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Two learning experiments were conducted to compare verbal and imagery based encoding techniques. Experiment I was conducted under rigorously controlled conditions comparing four encoding methods, and Experiment II compared the imagery matrix and eclectic verbal encoding in a classroom environment. The results showed the imagery matrix to be superior to all other methods and imagery based methods were superior over all to verbally mediated methods. The imagery matrix is suitable for use in an instructional technology.

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A COMPARISON OF VERBAL AND VISUAL IMAGERY LEARNING STRATEGIES: THEIR IMPORTANCE FOR INSTRUCTIONAL TECHNOLOGY

Introduction

The problem under investigation is that of determining whether subject selection, use, or manipulation of a specific information encoding technique produces differences in learning in comparison with the use of some other information processing method. The possibility that the adoption of specific strategies, tactics, or the purposeful manipulation of encoding elements by the learner will result in enhanced learning has been explored by Atkinson (1975), Bower (1970), Bugelski (1968, 1974), Cronbach (1975), Norman (1976), Paivio (1968, 1971), Rigney (1976), and Wood (1967). Generally positive experimental results and theoretically based support for the use of individually manipulated encoding elements as a method for obtaining enhanced learning rates increase the need to better define the role of these ideational elements in the intellective process. Currently there is very little evidence concerning (1) the characteristics of those ideational elements which can be reliably manipulated to influence learning, (2) the effects of the use of specific encoding techniques on acquisition, retention, relearning, and resistance to interference, (3) the effects of stimulus attributes on performance with different information encoding techniques, (4) the effects of the use of specific information encoding techniques on individual differences in learning performance, (5) the extent to which the effectiveness of different encoding methods generalizes across classes or types of information, (6) the amount of training required for subjects to use specific encoding techniques effectively, and (7) the instructional conditions

under which subjects can use one or another of those encoding techniques found to be effective.

The primary purpose of this study is to determine, under rigorously controlled conditions, whether the use of selected subject manipulated encoding strategies will result in differences in the response parameters produced in serial learning. The response parameters of interest here are acquisition rate, delayed recall, serial position effects, the influence of stimulus attributes, effectiveness in learning new material substituted into a prelearned serial list, and response orderliness and positioning. It was thought that a comparison of encoding techniques on a number of parameters would provide the most sensitive indicator as to the differing effects of several information encoding strategies.

A secondary purpose of this report is to evaluate in a classroom setting the generalizability of the most effective encoding technique to different levels of stimulus complexity, to evaluate its effectiveness in a more open learning situation, and to determine if the amount of training required to reach competence with its use can be attained in a conventional context.

This study is conducted as two experiments: Experiment 1 as a laboratory controlled evaluation and Experiment 2 as a field study conducted in a classroom.

Background

There is a basic question regarding the factorial structure of some of the recently defined encoding techniques. This issue concerns whether the individually manipulated encoding processes enhance the

traditional associative learning process or represent a different dimension in the information acquisition and retrieval process (Bugelski, 1970; Shepard, 1978). In any event there appears to be growing agreement that encoding is that process which transforms an environmental event into a suitable format for probable iconic, short-term, or long-term storage.

Reports by Atkinson (1975), Atkinson & Raugh (1974), Bower (1970), Bugelski (1968, 1970), Paivio (1971), and Smith and Noble (1965) provide evidence that some methods of manipulating elements of the subjects' information mediating process have a positive, significant effect upon the information acquisition process.

The extent to which individual control of mediating processes can influence the rate of acquisition apart from other parameters of learning remains to be determined. It is apparent, however, that the study of mediational or facilitative processes is an important, new direction in learning research. Melton (in Melton & Martin, 1972) describes the direction and scope of this trend:

> The traditional association theory, which dealt with associative dispositions between input and output events according to a conditioned response analogy, has given way to theories in which the learner is conceived to be an active processor of input events (stimuli) and a selector of output events (responses). . . . The first two developments that have been mentioned are two reliable symptoms of the intellectual release that has occurred with the breaking of the traditional constraints on systematic thought about human learning and memory. . . . The coding concept and the many terminological variants of the idea of coding-encoding, recoding, decoding, functional stimuli, "chunks," subjective units are the third [major development]. The core intent of this idea is that between the external world and a human's memorial representation of that external world there operate certain processes that translate external information into internal information. These

> processes may in part be selective, or elaborative, or transformational; some may be optional while others are obligatory; . . . the critical determinants of learning and remembering are to be found in the coding response to an experienced event, pair of events, or sequence of events. Further, it is implied that coding responses have their components and structure determined by the preexisting structure of the brain, . . . as well as by transient factors such as information-processing sets, whether generated by context, instructions, or self-instruction in combination with habit. (pp. xii-xiii)

Concordance on the constituents of the transformation function exists only in a very general sense. In contrast to the apparently objective detachment of Melton's (Melton & Martin, 1972) lucid description of the emergence of a conceptually orderly encoding process and its parameters there is some disarray in the many approaches to this problem. The descriptive terminology appearing in the literature provides a diverse and somewhat confusing picture of the encoding function and the probable underlying mechanisms. Underwood (in Melton & Martin, 1972) vividly describes the proliferation of terminology and ideas recently associated with encoding and the memorial process:

> Memories now have attributes, organization, and structure. There are storage systems, retrieval systems, and control systems. We have iconic, echoic, primary, secondary, and short-, medium-, and long-term memories. There are addresses, read-out rules, and holding mechanisms; memories may be available but not accessible (or is it the other way?). Our memories are filled with T-stacks, implicit associational responses, natural-language mediators, images, multiple traces, tags, kernel sentences, markers, relational rules, verbal loops, and one-buns. . . . To focus on coding theory is to focus on the meaning and implications of many of the terms listed somewhat haphazardly above. (p. 1)

The hypothesis that information transfer from the environment occurs in the form of incremental development of associative processes as

a function of conditions related to the recency and frequency of the stimulus presentation and its similarity to earlier stimuli has been strongly supported by both theory and experiment since Hartley's synthesis of the association concept in 1749 (Mandler & Mandler, 1964). Theoretical constructs supporting the idea of one-trial learning, on the other hand, have not been well received or supported. Underwood and Keppel (1962) explored theoretical positions and experimental evidence in support of one-trial learning. They concluded that (1) data offered in support of one-trial learning could be as easily interpreted to support incremental learning, and (2) the defining of trials by arbitrarily assigned time values as well as other methodological problems makes a position on one-trial learning difficult to define or support. These views are in close agreement with those of Bugelski (1962) that time and trials appear to be *interchangeable or equivalent* units for measuring learning rate. The concept of incremental growth of associative strength over trials as a function of the stimulus melieu is being subjected to modification, however, by the notion that the individual's learning strategies and motivations may alter the rate at which the incremental associative process occurs.

The concept that encoding material to a different, perhaps more meaningful, form increases learning of trigrams under certain conditions was investigated by Underwood and Keppel (1963). Two groups of subjects (each with five subgroups): an instructed group, which was told that each trigram could be changed to spell a meaningful word, and an uninstructed group; both learned trigrams which could be rearranged to form a meaningful word. The subgroups differed on instruction and on whether they were required to supply the trigram as presented or as a

meaningful word. Those subjects reporting trigrams as words learned more rapidly than those not using this form of coding. However, those instructed subjects who coded the trigrams as words during learning and were required to report them in the original order produced fewer correct responses and made more errors than the uninstructed subjects. Apparently, one encoding step may facilitate, but an additional step may degrade response performance.

A relatively recent encoding concept, the use of constructed imagery as a mediator in stimulus-response bonding, has been resurrected in part from ancient Greek pedagogy (Yates, 1966) and in part from a reviving interest in the phenomenon of imagery (Hebb, 1960, 1968; Holt, 1964) and is receiving considerable experimental attention. The possibility that imagery is a useful mediator has been examined in the context of the conceptual peg hypothesis (Paivio, 1971) and in the context of subject generated stimulus imagery (Paivio, 1966; Smith & Noble, 1965). The conceptual peg hypothesis holds that concrete stimuli may stimulate the formation of integrated, holistic, ideational representations which may be expressed as mental images (Anderson, Goetz, Pickert, & Halff, 1977) more easily than abstract stimuli. This organizing hypothesis is offered as partial explanation for the fact that concrete language makes word pairs and sentences more memorable. Subject generated imagery based on abstract stimuli, on the other hand, may require individual motivation and effort to develop a constructed image to a reportable or manipulable level (Bugelski, 1970). The use of imagery as a mediator in stimulus-response bonding in both serial learning and paired associate studies has usually been reported to enhance learning (Bower, 1970; Bugelski, 1968, 1974; Paivio, 1969). However, other studies have reported the use of

constructed imagery mediation to have less effect on acquisition rate than other types of mediation (Wood, 1967).

The use of constructed imagery as a subject manipulated mediator in an experimental learning situation poses a number of theoretical problems. Bartlett (1932) proposed a constructive concept of thinking and memory in which ideas and events are not stored as fixed entities. Rather, recall evolves from a reassembly of sensations, movements, and perceptions which are organized by past motivations to induce representation of past events. In this view, which has received wide acceptance, imagery as a continuous phenomenon representing ideas or recalled events could not survive the reconstructive process to exercise a significant role in ideation. Recent support for the constructive approach to ideation has been provided in reviews by Cofer (1973) and Plylyshn (1973).

Shepard (1978) in a long-term effort focused upon evaluating the function, structure, and characteristics of mental imagery and its role in cognition developed a position based upon both research and anecdotal material. He viewed imagery as sharing many properties with visual perception, retaining the attributes imparted during perception of the imaged object, e.g., apples are perceived in imagery as edible and ice as cold and wet. Such attributes were deemed useful in making judgments and comparisons and in other cognitive functions. Shepard cited studies on imagery rotation as providing evidence for spatial and positional orientation properties of imagery. In these imagery rotation studies the subject's task was to match an imaged object with one of a set of displayed figures. At least one of the figures in the set represented the imaged object presented in a rotated perspective. The subject had to subjectively rotate the imaged object to approximately the same

orientation as the form on display for a correct match. The results of these studies and those using a grid probe technique which required the visualization and recall of forms in space were seen as supporting the role of imagery in ideation. The extent of imagery rotation and the amount of displacement of visualized space were related to response latency, a critical factor in relating these data to a theoretical position.

Shepard was impressed by the many accounts of prominent scientists, e.g., Faraday, Maxwell, and Einstein, whose introspective accounts gave a predominant role to the experience of imagery and imagery modeling and manipulation in the solution of the fundamental problems they resolved. He cited these accounts as descriptive evidence of a salient function of mental imagery in ideation.

Anderson (1978) performed an intensive review of the current evidence and theoretical positions on the phenomena of mental imagery. The basic issue he considered was not whether imagery existed but the nature of the representations which underlie it. Two basic views of representations for imagery were examined. One position holds that visual imagery is encoded in terms of properties which are spatially and modality specific. A sharp distinction is made here between the codes used for verbal and visual information. The contrasting position is that imagery is encoded in an abstract propositional format which is essentially the same as that used to code verbal information.

Anderson's analysis took into account the possible behavioral outcomes from several encoding models. He concluded that attacks on the logical coherence of pictorial representations lack validity and that coherent dual-code models involving pictorial and verbal representations

can be developed. On the other hand, empirical demonstrations consistent with pictorial representations fail to provide evidence that would discriminate such representations from propositional ones. Anderson concluded that the failure of the anti-pictorial and the pro-pictorial arguments flows from a fundamental indeterminancy in deciding issues of representation. Wide classes of different representations may yield identical behavioral predictions and this potential for mutual mimicry holds between propositional and dual-code (pictorial-plus-verbal) models.

Methodological problems are such that there are only indirect or inferential indications that imagery or sensation which individuals perceive and report as imagery exists as an effector component in intellective functioning.

The crux of the problem is that constructed imagery remains elusive as an objectively measured phenomenon, even though subjects respond to directions concerning imagery as though to an authentic stimulus (Bugelski, 1968, 1974; Paivio, 1969). The attractiveness of imagery as a mediator is that it is widely shared as a reportable experience, subjects respond predictably to directions relating to imagery, and they appear to be capable of manipulating imagery content, form, and spatial relationships (Bower, 1970; Shepard, 1978). Further, imagery appears to have a salient but undefined role in the mechanics of ideation (Hebb, 1968; Holt, 1964). Whether some part of this imaginal function is in consonance with the associative or other learning processes remains to be determined.

Learning traditions or systems which were available to teachers in ancient Greece or scholars in the Middle Ages were based on the concept of individually constructed imagery and ideational space as described by

Yates (1966). The oldest and most basic method is an artificial memory which is established from places and things, the method of Loci et Res. The method of Loci was depicted in an anonymous manuscript entitled Ad Herennium dating from 55 BC. In the use of this method one, as a mental procedure, remembers a number of places in an order such as the rooms of a house, a known lane or street, or other intimately familiar place. In each place a locus is established for storing images. Two types of images may be stored in these loci: images for things, and images for words. When material is to be stored, the student develops an image or representation of the first item and mentally places it on a visible area in the first location to form a stable figure-ground relationship. Images of the other items to be learned are stored in successive loci. Retrieval of the stored material is accomplished by introspectively retracing the route, reviewing each locus, and resurrecting the original image or representation stored there. After retrieval this material is available for response as though it were in short-term memory.

Yates (1966) described a number of mnemonic devices, many of which were designed with the loci as grid positions in a matrix. The matrix grids were usually designated with well known mythological names to identify each space. These identified matrix spaces were then used for imagery storage as in the method of Loci et Res. The imagery matrix concept has since been refined by the development of a structurally more elegant alphanumeric cueing system (Furst, 1949; James, 1950).

Smith and Noble (1965) evaluated the effects of using an alphanumerically cued imagery array as a mnemonic aid, as described by Furst (1949), in the serial learning of consonant-vowel-consonant (CVC) lists

of low, medium, and high scaled meaningfulness. The subjects were 126 college students arranged in matched pairs at seven ability levels. One member of each pair was assigned to the experimental group and the other to the control group. The experimental group was given 1 hour of instruction and 1 hour of practice in the use of the mnemonic technique. Both groups were given 20 learning trials, followed by 10 relearning trials. The experimental group had a significantly higher acquisition rate than controls on the learning trials, but there was a complex interaction between ability and meaningfulness of the CVCs with the superiority of the experimental group being accounted for by improved performance of the low ability subjects. The technique was judged useful in the retention of material of low and medium meaningfulness but not for more meaningful material. Senter (1965) reviewed a number of popular books on memory improvement, including his personal experience with use of the alphanumerically cued mnemonic technique described by Furst (1949). He reported that use of the technique increased his acquisition rate, improved his retention, and reduced the effects of retroactive inhibition.

A study by Paivio, Yuille, and Smythe (1966) addressed the relative influence of abstractness, imagery, and meaningfulness on mediation in paired associate learning. Concreteness and imagery as stimulus attributes were both more effective as mediators on the stimulus side than on the response side of word pairs. Paivio interpreted this as an indication of the two attributes sharing an underlying process. Adding meaningfulness to one side of associate pairs of abstract nouns enhanced performance. The magnitude of this effect was the same whether the meaningful item was on the stimulus side or the response side. Adding meaningfulness to concrete associate pairs had no effect on

learning. Subjects most frequently reported imaginal mediation with concrete noun pairs, and verbal mediation predominated with abstract noun pairs. Learning was most rapid with reported imaginal mediation, intermediately rapid with verbal mediation, and slowest with no reported mediation.

Paivio (1967) examined the distinctive stimulus features of specificity, imagery, and meaningfulness in the context of free recall and paired associate learning. He found that on both the stimulus and response side of paired associate learning changes in imagery influenced learning rate more than changes in the other attributes. As in the earlier studies imagery influenced learning more on the stimulus side than on the response side. Imagery was more highly correlated with learning scores than was meaningfulness. Positive effects were also shown for concreteness and specificity on free recall.

Wood (1967) conducted a series of five experiments to determine whether a mnemonic system influenced recall and, if so, to identify the relevant elements of the system. Factors such as presentation rate, transfer paradigm, type of list, and list abstractness were manipulated to determine whether differential effects relative to a control group were achieved.

Wood interpreted his findings as indicating that the use of a mnemonic as a stimulus aided acquisition and that intrusions into a serial list were as likely with the use of a peg word mnemonic as with serial learning. Further, his results indicated that use of imagery did not facilitate performance relative to a group using verbal mediation for paired associate stimulus-response bonding. He also found that the linking of word lists with bizarre imagery facilitated acquisition relative

to the use of free recall, that primacy and recency effects were significantly reduced using either the mnemonic peg words or imagery linking of response lists, and that a 5-second presentation rate was more effective for use with the verbal mnemonic and imagery bonding than the 2-second rate.

Wood indicated that the more rapid acquisition and lack of serial position effects of primacy and recency associated with use of the mnemonic were due to the facilitating effect of the prelearned stimulus and the fact that use of paired associate paradigms did not generate serial position effects.

Bugelski, Kidd, and Segmen (1968) studied the effect of a mnemonic consisting of an imagery array generated from number and word rhymes (one-bun, two-shoe, etc.), on serial learning using three groups. Explicit imagery instructions were given to the experimental group. One of the two control groups was given the mnemonic without specific imagining instructions, and the other control group received only instructions related to the learning task. Each of the three groups was further subdivided into three subgroups each of which was given a different word exposure time, either 2, 4, or 8 seconds, for encoding each stimulus. The imagery instructed experimental group outperformed the control group, and the experimental group assigned the 8-second exposure outperformed those with 2- and 4-second exposure times. Bugelski discussed the theoretical aspects of working with imagery as an experimental construct and subject responsiveness to directions concerning "pictured" objects.

Paivio (1968) replicated some elements of Bugelski's 1968 study and found that imagery instructions are an effective component of the

mnemonic and that under imagery instructions the differences in effectiveness due to concreteness or imaginability which he had previously observed disappeared.

Persensky and Senter (1968, 1970a, 1970b) performed a series of three studies investigating the relative efficacy of mnemonics in serial learning, the role of "bizarre" imagery in mediating mnemonic stimulus response bonding, and the effects of following instructions during the use of a mnemonic technique. They reported that use of a mnemonic technique similar to the one described by Furst (1949) facilitated serial word list acquisition, that instruction in the use of "bizarre" imagery aided the application of the mnemonic, and that identification of subjects who failed to follow directions for applying the mnemonic technique and removing their data from the analysis improved differentiation between mnemonic experimental and control groups.

Kulhavey and Heinin (1974) compared four types of encoding procedures for the learning of categorized noun lists under serial and total presentations. The encoding instructions described the use of four encoding techniques: imagery, clustering, developing a narrative, and learn. A 3-second presentation rate was used for all groups during each of the three trials. Imagery was the most effective encoding technique on each of the three trials. However, though the mean differences were statistically significant, they were not large.

The acquisition of information by use of mnemonic techniques and its long-term retention were evaluated by Wortman and Sparling (1974). They used imaginal (bizarre and common imagery) and verbal mediators with concrete and abstract stimuli. Retention was measured immediately and after a delay of 1 week. The bizarre and normal imagery produced more

rapid learning for both concrete and abstract words relative to verbal mediation. For all groups more concrete than abstract words were learned. After 1 week, 30% of the concrete and 50% of the abstract words had been forgotten. There were no differences in forgetting rate across mediation techniques. They concluded that imagery mediated information is retained to the same extent as verbally mediated material.

Lowry (1974) compared three encoding strategies: the use of imagery, sentence linking, and repetition on serial learning. The experimental design allowed for analysis of negative transfer, retroactive interference, and 48-hour interference using an AD-CD paradigm. A 4-second stimulus presentation rate was used throughout. The subjects using a mnemonic encoding method differed in performance on acquisition rate only. Lowry concluded that mnemonics effects are centered on the associative process, and only on acquisition.

Paivio (1969) examined nonverbal imagery and verbal symbolic processes in associative meaning, mediation, and memory. He hypothesized that both processes can be made available, through use of stimulus attributes and design of experimental procedures, as associative mediators or memory codes. Imagery evoking value was assumed to vary directly with item concreteness. Verbal processes, on the other hand, were thought to be independent of concreteness but functionally linked to meaningfulness and codability. Stimulus characteristics are presumed to interact with mediation instructions, presentation rates, and type of memory. Paivio in evaluating both performance and subjective data which were developed in the test of the hypotheses concluded that imagery-concreteness is the most potent attribute yet identified among meaningful items. He indicated that meaningfulness and other relevant attributes

are relatively ineffective in influencing the mediation of stimulus-response associtations. He found that both imagery and concreteness can be effectively manipulated by instructions, but that imagery is a preferred mediator, particularly when one or both members of a stimulus response pair is concrete. Paivio believes that imagery and concreteness are differentially effective in sequential and non-sequential tasks.

Bower (1970) in an analysis of a mnemonic device developed the rationale for the more rapid verbal learning attributable to an imagery matrix of the one-bun, two-shoe variety. Bower's primary interest was in the characteristics of imagery, the organizing effects of the concrete-abstract continuum on ideation and imagery formation, and the sensory-modal imagery interaction. Bower accepted the imagery complex--visual imagery, memory images, and imaginal representations--as entities whose existence can be inferred from several sources of evidence. Two pieces of evidence appeared especially significant. The first was that subjects who manipulated several images simultaneously established associations which could be recalled whether there was intention to learn or not. The second evidence was the interactive influences of imagery and sensory thresholds. Bower cited evidence that tasking a sensory mode associated with imagery reduced the effectiveness of the imagery, e.g., a visual tracking task interferes with the generation of visual imagery more than a tactile tracking task. Further, the generation of visual imagery appears to raise visual detection thresholds. Additionally, Bower detected imagery-word interaction in cross-modal response time data which was interpreted as evidence of two separate processes for imagery generation and word encoding.

Bugelski (1970) examined the evidence for imagery as a construct,

its role in the ideational processes, the imagery evoking capacity of words, and evaluated the effectiveness of imagery as a mediator in the development of stimulus-response associations.

Bugelski's research in a series of studies indicated that the instructed use of imagery provided significantly more effective mediation in recalling short serial strings of words than other mediators which were investigated. Bugelski developed a unique approach to the study of imagery and the ideational processes through use of special association procedures, "instructed" incidental learning experiments, and other techniques. In the association study, he asked subjects to respond to a stimulus word with their first thought or impression. The most common response was a symbolic representation of a described image. He concluded from these studies that (1) most thinking appears to be very concrete, i.e., images or representations, (2) most words evoke imagery or symbolic representation at some level, even abstract words are symbolically represented, (3) imagery evoked in these studies produced individualistic rather than stereotyped responses, (4) imagery perhaps in conjunction with other attributes appears to provide a significant amount of meaning for both verbal and non-verbal events, (5) once imagery is generated it is as well remembered as imagery constructed for a specific learning purpose, and (6) imagery is perhpas a major, essential component in the ideational processes.

Bugelski (1974) assessed Paivio's (1971) contention that imagery mediation was effective in parallel (paired associate) processing but not in serial learning. Bugelski's experimental subjects, assigned a task of learning a 20-word list in serial order, were instructed to generate an image for each stimulus word and to link this image with the image of the

adjacent word. The differences in mean number of words recalled between the experimental and control group after one trial were quite large. Bugelski concluded that imagery mediation was as effective in sequential processing as in parallel processing.

Atkinson (1975), Atkinson and Raugh (1974), and Raugh, Schupback, and Atkinson (1975) examined the problem of using an imagery mediated mnemonic procedure in teaching a foreign language vocabulary. The method for applying imagery mediation to language instruction was adapted from a proposal suggested by Furst in 1949. The mnemonic procedure is based on the concept of a key word which forms an acoustic link to the foreign word and an imagery link to its English equivalent. The acoustic component of the key word is formed by the selection of an English word(s) which sounds as similar as possible to part or all of a foreign word, e.g., "Pierre is sick" is an English key word for the Russian word "persik" (peach). The imagery link is formed by constructing an image for "Pierre is sick" and mediating it with an image of "peach." Thus an acoustically based imagery mediated bond is established between the Russian word "persik" and the English word "peach." The thought of "peach" and the related imagery raise the acoustic link and the pronunciation simile for "persik." Atkinson and associates utilized a previously developed computer assisted instructional program for presenting the mnemonic supported experimental segment. Both student performance in learning and student acceptance were measured over time. The mnemonic students on a controlled learning task of 120 vocabulary words recalled 34% more than the control group. On a delayed comprehension test 6 weeks later, the mnemonics group again recalled 34% more than the control group.

Research Considerations

The basic question addressed in this paper is whether subject directed manipulation of subjective elements of the learning system influences the information encoding process, and, if so, which elements are most influential. That is, we ask whether the use of a particular encoding strategy affects the rate of information acquisition, produces differences in the amount or accuracy of storage and recall, or influences the general resistance of the learned information to interference or displacement by the learning of new material or material substituted into the same serial context.

The question posed is of necessity broad because the encoding process appears from any perspective to be complex and multidimensional, interacting with many other ideational processes. The problem of identifying the ideational components of the information encoding process and ascribing functional roles to them in a subject directed learning context is exacerbated by the lack of well defined encoding techniques for comparison which have been tested over a number of learning tasks and stimulus conditions. Additionally, there is a lack of knowledge for many encoding techniques about relationships between performance and individual differences. From this perspective there is a need for a broad study addressed to this problem domain which would: (1) provide a description of relevant ideational elements and encoding strategies, (2) provide hypotheses which focus upon the general problem of differences in encoding strategies, the functions of ideational elements in the encoding process, the influence of stimulus attributes, and the possible effects of individual differences, (3) evaluate the performance of each encoding strategy on standardized serial learning tasks, taking into account stimulus

attributes, differences in response characteristics, and the possibility of individual differences being related to ideational elements which are integral with the encoding strategies used, and (4) evaluate the amount of training required for the use of an encoding method and its effectiveness when used in a classroom situation.

The goal of this research is to evaluate encoding strategies and their potential application to an instructional technology which is currently under development. This instructional methodology is being designed to capitalize on the subject's ability to manipulate ideational elements in order to form a synthesis of stimuli and cognitive elements which can then be recalled, subjectively evaluated, and manipulated for use in making judgments, comparisons, or performing other operations required for more effective academic achievement. This research is performed in two experiments. Experiment 1 compares encoding strategies under rigorously controlled conditions. Experiment 2 compares encoding strategies in a classroom environment on both simple and complex material.

Encoding Strategies

The encoding strategies were selected to provide a maximum of subject control over the ideational aspects of the encoding process. The considerations for development of encoding strategies centered on two basic classes of ideational elements. These were: (1) a verbal dimension which utilized the subject's ability to manipulate verbal stimulus material upon demand, and (2) an imaginal dimension based on subject generated or constructed imagery of stimulus events.

To give the subject as much encoding control as possible of the verbal elements, two methods were selected: one of which involved

stimulus repetition, and the other of which involved stimulus linking or chaining. To provide for control of imagery ideational elements again two methods were devised: one of which involved stimulus linking, as did one of the verbal element methods, and the other of which involved storage of an imagery stimulus in an imagery matrix.

The four encoding strategies developed as subject manipulated, mediating techniques for serial learning tasks were:

(1) Repetition: This technique is essentially the same as the one for which Ebbinghaus developed the classic quantitative methodology in the late 19th century. The subject is directed to repeat each stimulus word as it is presented, then repeat it with previously presented stimulus words until the next stimulus word is presented.

(2) Semantic Linking: This technique is based upon the idea (Bower & Clark, 1969) that use of verbs, adjectives, or adverbs used in conjunction with words to be learned in a serial list increases learning rates over subject selected mediating techniques. The subject approaches the learning task in much the same manner as for the repetition technique except that a modifier or linking word of the subject's choice is used between each pair of words presented in the stimulus list. The rationale for the increase in learning is that the modifier adds meaning or attributes to the word and strengthens the associative bonds to proximal words in the list.

(3) Imagery Chaining: This is an imagery based encoding technique similar to that described by Bugelski (1974) in which a constructed image of each stimulus item is subjectively overlapped with the image of the adjacent items as described by Furst (1949) to form a concatenation of images. Recall is achieved by introspectively examining or tracking

from one image to the next overlapped image and recognizing the contents of each.

(4) Imagery Matrix: The general elements of the imagery matrix method have been described by Bower (1970), Furst (1949), James (1950, p. 696), and Yates (1966). It has an alphanumeric code (Furst, 1949; James, 1950) which the subject uses to associate a word with each integer. Each word so associated is converted by the subject into a stable, familiar visual image which serves as a cue or, more specifically, as an imaginal storage box for stimulus material to be acquired. Each integer used refers to a serial position and a letter (phonic) which forms the basis for the word and image used as a storage locus. The natural and universally known order of the integers provides, via the alphanumeric code, the framework to order the cue (storage) image or words. The stimulus to be acquired is also converted into an image which is combined with the storage box image in a figure-ground relationship. The stimulus image is then recalled by introspective observation of the storage box image.

Hypotheses

The questions related to the study of subject manipulated encoding strategies are addressed by three categories of hypotheses. These general groupings of hypotheses are focused, respectively, on (1) the comparative performance effectiveness of encoding strategies, (2) the characteristics of learning performance and the effects of stimulus attributes for each encoding technique, and (3) the relation between individual differences in learning performance, aptitude, and imagery manipulating ability for each encoding method.

The first class of hypotheses is based on the contention of Bower (1970), Bugelski (1968, 1970, 1974), and Paivio (1966, 1967, 1968, 1969) that subject manipulated, imagery based encoding strategies provide superior information acquisition rates over subject selected or other encoding strategies. Wood (1967) described a study by Wallace, Turner, and Perkins (1957) in which subjects working at their own pace used imagery mediation to bond 500 word pairs. The accuracy of recall of the response word on the first trial when given the stimulus word exceeded 95%. Bugelski (1970) postulated that imagery or some form of symbolic representation is a component of the ideational process which influences thinking, judgment, and learning. Bower (1970) described an imagery based mnemonic system (a cued imagery matrix) whose use he postulated would raise the user's information acquisition rate above that for other encoding techniques. Consideration of the evidence for the probable performance differences of the repetition, semantic linking, imagery chaining, and the alphanumerically cued matrix encoding methods provide the rationale for the first hypothesis. The reported function of imagery as an effective mediator, apparently superior to other encoding strategies, defines the context for the second hypothesis. Bower (1970) described studies in which the use of a cued imagery array such as the Loci et Res improved acquisition. Bugelski (1968) obtained superior learning rates with a one-bun, two-shoe type mnemonic. Consideration of these studies suggests a third hypothesis directed at comparative performance effectiveness of encoding strategies. These three hypotheses are:

(1) That information encoding strategies which differ on the elements to be manipulated by the subjects will differ on information

processing effectiveness in terms of rate of acquisition, accuracy of recall over time, and resistance to the interference of new learning.

(2) That among the encoding methods evaluated in this study, the imagery based techniques will provide subjects with more effective performance on all learning tasks than the non-imagery techniques.

(3) That the use of an alphanumerically cued imagery matrix as a mediator will provide the subject with more effective performance across all learning tasks than use of the imagery chaining method.

The second class of hypotheses is concerned with the performance characteristics of the different encoding strategies related to serial position association effects, the interference effects of learning new material within the context of a previously learned word list, the effects of the concrete-abstract dimension upon imagery based encoding methods, the accuracy of ordinal positioning, and the orderliness of responses.

Bugelski (1968, 1974) hypothesized that imagery mediated bonding between adjacent words, unlike serial position associations, were equally strong in both directions and would be more resistant to associative interference than non-imagery based encoding techniques. Paivio (1969, p. 257) proposed that imagery was primarily a parallel information processing medium and was not suited for serial processing unless linked to a sequentially organized verbal system such as the one-bun technique. Bugelski (1974) presented data indicating that subjects could connect imagery in a serial process such that each image based response served as the stimulus for the next response. Bugelski (1974) indicated that imagery linked serial responses are more resistant to serial position effects than verbally associated responses. Bower

(1970), Bugelski (1968, 1970) and Paivio (1969) indicate that imaginally mediated response bonding may occur in one trial and should be more resistant to the interference of serial position effects. One implication of one-trial learning is that new material may be easier to learn in a previously established context. These considerations concerning resistance to interference from serial position effects and learning of new material lead to the hypothesis:

(4) That the repetition method will be most vulnerable to associative interference as measured by primacy and recency effects and by learning a list composed of both old and new items; that learning performed using the linking methods (semantic linking and imagery chaining) will be less influenced by associative interference than repetition learning; and that learning performance would be least affected by serial position associations or by interference from learning new material when using the imagery matrix method.

Paivio and associates (1968b) had 925 nouns rated on concreteness, imagery, and meaningfulness. The results were interpreted as indicating a probable common underlying dimension for words rated high on concreteness and imagery. Data were presented by Paivio (1966, 1968) supporting the idea that subjects formed images more easily from words rated high on concreteness than from abstract words. Bower (1970) hypothesized a concreteness-abstraction continuum for words and that words rated higher on concreteness were easier for subjects to use in forming imaginal response bonds to a stimulus. Bugelski (1970) concluded that, although more time was required, abstract words could be transformed by most subjects into symbolic representations which could be manipulated in much the same way as the constructed imagery generated

from concrete words. The hypothesis relating to concreteness as a stimulus attribute which may differentially influence encoding effectiveness takes the form:

(5) That the imagery based encoding methods will show larger differences in item difficulty between concrete and abstract words than the non-imagery based encoding techniques, and that concrete words will be less difficult to learn.

The appearance of orderliness and correct ordinal position replication as a response to learning a stimulus list is probably affected to some extent by stimulus characteristics, method of presentation, and the encoding method used by the subject. Shuell (1969) indicates that subjective organization or the amount of order in responses during free recall increases as a function of number of trials. In addition, responses may cluster in any of several meaningful categories of stimuli. Determan and Brown (1974) found increases in item retention related to total study time in both ordinal and free recall, while increases in order retention were a function of study time per item. Bugelski (1968, 1974) presented data which indicate that choice of encoding method may influence the rate at which correct ordinal position is achieved in the learning of short serial lists and that the use of imagery associations for learning serial lists increased both total recall and the number of items in correct ordinal position. Wood's (1967) findings showed that use of a cued mmemonic had a significant positive effect upon the ordinal positioning of responses. The imagery chaining technique develops serial associations through overlapping of stimulus images during learning. This overlap process should maintain serial order and if the initial stimulus is anchored properly provide accurate positional responses.

The alphanumerically cued imagery matrix provides a discrete, positionally specific imaginal cell for each stimulus. Thus accuracy of ordinal positioning of responses should be very high. To explore the possibility that imagery mediated techniques provide more accurately ordered and positioned responses than other information processing methods, the hypothesis comparing the orderliness and ordinal positioning effects of imagery based encoding methods is expressed as:

(6) That the use of the repetition encoding method will result in less orderliness and less accurate ordinal positioning in the responses on all learning tasks than the use of other encoding methods. The use of the semantic linking and imagery chaining encoding methods will provide an intermediate level of orderliness and positioning accuracy. The use of the alphanumerically cued imagery matrix will provide superior ordinal positioning responses over other encoding methods.

The third class of hypotheses deals with individual differences as observed in the measurement of aptitudes, imagery scale scores, and information encoding performance. Horn (1968) has suggested that speed and the span of apprehension represent anlage functions and provide reliable prediction of differences in measured aptitudes or cognitive functions. Horn (1968) and Lyon (1974) reviewed a number of studies in which coding, grouping, classification, and other strategies were used to increase the span of apprehension. Two general conclusions were reached. First, the use of coding strategies was effective in increasing the amount of information apprehended. And secondly, the use of such strategies when used by all subjects did not reduce differences normally found between those with different aptitude levels. Such techniques were as advantageous for the gifted as for the retarded. On this basis one would expect

that the use of a different encoding technique by each group would produce mean learning differences between groups but would not reduce the differences in learning rate associated with different aptitude levels within a group.

There are few published data on the relationship between cognitive abilities and the capability to subjectively construct or manipulate imagery as a form of symbolic representation. Using a sensory imagery intensity scale Brower (1947) found no relation between the self-rated intensity of perceived sensory imagery for each mode (warmth, color, kinesthesia, and others) and scores on the Otis Test of Mental Ability (Form B). It is reasonable to propose that those subjects performing most effectively using imagery based encoding methods should show a relationship between learning performance and responses on imagery scales. The hypotheses addressing the questions associated with individual differences and performance through use of the different encoding techniques are straightforward. They are:

(7) That each of the encoding groups will show the same general pattern of correlation between learning performance and measured aptitude on the different learning tasks.

(8) That those encoding groups using imagery based encoding methods will have significant correlations between learning performance and scores on the Gordon Test of Visual Imagery Control and the Mullins Imagery scales.

The application of the imagery matrix method in a practical situation appears more complex than use of a familiar encoding method such as repetition. The matrix method requires training and practice for efficient encoding of even simple material. The effectiveness of

group explanation and demonstration, group interaction, and practice with feedback of results in the presence of peers has not been evaluated for the imagery matrix method. It is thought that training on the matrix method in a classroom would be equally as effective as that conducted for individuals and small groups in Experiment 1. The hypothesis concerning the classroom training and application of the imagery matrix encoding system is expressed as:

(9) Students can be trained in the use of the imagery matrix learning system to increase their ability to acquire and recall information in the immediate context of the classroom setting and that training of students to proficiency in the use of the system for application to various stimuli can be accomplished during a normal 50-minute classroom period.

The range of stimuli that an encoding method can process is an important indicator in identifying its functional role in relation to other encoding methods and ideational formats. Assessment of the capacity of different encoding formats to acquire, store, and recall information and the arrays in which this information is ordered may provide insights into essential structural features and contribute to theory or application. Verbal expression, for example, is assumed to be limited to unidimensional serial processing, whereas Bower (1970) has described constructed mental imagery as having the potential for storing information in several dimensions and orders. Bugelski (1970) and Shepard (1978) have provided evidence that constructed mental imagery may store large amounts of complex information in a single constructed representation. The current evidence appears to support the contention that imagery can be used to store complex information in a single

representation. The hypothesis in support of this position is expressed as:

(10) The use of the imagery matrix encoding method will provide significantly higher acquisition rates for complex material than use of other information encoding techniques.

A number of follow-on analyses will be accomplished to compare data in Experiment 2 with that from Experiment 1 to evaluate the quality of responses obtained with complex stimuli and to further evaluate the extent to which differences in learning performance will vary with aptitude.

Synopsis of Hypotheses

A synopsis of the hypotheses is provided as a convenient reference.

1. Encoding strategies will differ in information processing effectiveness.

2. Imagery based encoding techniques will be more effective in processing information than non-imagery based techniques.

3. The imagery matrix method will be superior to the imagery chaining method.

4. The order of encoding strategies on susceptibility to interference from primacy and recency effects or the learning of new material will be repetition, semantic linking, imagery chaining, and the imagery matrix.

5. The imagery based encoding method will show larger differences in encoding concrete and abstract words than non-imagery methods.

6. Orderliness and serial position of responses will increase by

encoding method in the order of repetition, semantic linking, imagery chaining, and imagery matrix.

7. Each of the encoding groups will show the same general pattern of correlation between learning performance and measured aptitude on the different learning tasks.

8. Performance on the imagery based methods will correlate significantly with several imagery measures.

9. The imagery matrix method can be efficiently taught in a classroom context.

10. The imagery matrix method will be significantly superior to other encoding techniques in the acquisition of complex material.

EXPERIMENT 1

Method

Subjects

Subjects were 120 students recruited from Trinity University in San Antonio paid to participate at an hourly rate. Each subject was scheduled for four sessions: a preliminary testing session, a training session, an initial learning session, and a recall and relearning session. The last two sessions were scheduled 24 hours apart, and remuneration was contingent upon and paid after completion of the last session. More than 161 students were recruited for participation in the study. Ten qualified subjects received the experimental stimulus lists in the wrong order and their data were set aside; five subjects were released for cause, one of whom was a diagnosed aphasic, and 26 students failed to meet a scheduled experimental session and were released. The mean age of the final subject group was 20.1 years, mean education was 2.3 years of college, and the mean number of children per family was 3.4. The complete demographic summary for the subject group is provided in Tables 1 and 2.

Materials and Equipment

Four tests and an End of Treatment Questionnaire were administered in this study. The tests used were (1) The California Test of Mental Maturity (CTMM) Level 5, (2) The Spelling Speed Test (SST) (Noble et al., 1966), (3) The Gordon Test of Visual Imagery Control (GOTVIC), and (4) The Mullins Imagery Scales (MIS). The California Test of Mental Maturity is a standardized aptitude test which provides six subtest

Table 1

Demographic Characteristics for Subjects by Encoding Technique

	Encoding Technique														
	Total Sample			Repetition			Semantic Linking			Imagery Chaining			Imagery Matrix		
	Mean	σ	Range	Mean	σ	Range	Mean	σ	Range	Mean	σ	Range	Mean	σ	Range
Education	2.3	1.3	5	2.3	1.6	4	2.7	1.1	3	2.0	1.0	3	2.3	1.4	5
Age	20.1	3.0	28	20.7	5.0	28	20.6	2.4	10	19.6	1.9	9	19.8	1.7	7
No. Children	3.4	1.9	9	3.9	2.1	9	3.7	1.8	7	2.7	1.5	5	3.1	1.9	9
Gender: Male (n)			60			18			8			11			16
Gender: Female (n)			70			12			22			19			14

*Total N = 130; for Groups I, II, III, and IV n = 30 each. Ten alternates were selected but did not appear in any treatment group.

Table 2

Educational Level, Academic Major, and Father's Occupation for Subjects
($\underline{N}$ = 130)

College Class			
Freshmen	48	Senior	20
Sophomore	28	Graduate Student	7
Junior	27		
Major			
Humanities	15	Physical Sciences	3
Social Sciences	52	Other	30
Biological Sciences	19	Undecided	11
Father's Occupation			
Professional	79	Craftsman	1
Manager, Foreman	8	Operatives	2
Farmer	2	Service	2
Clerical	1	Not in Labor Force	10
Sales	5	Deceased	20

scores and a total score. The subtest scores are Logical Reasoning, Numerical Reasoning, Verbal Reasoning, Memory, Language, and non-Language. The Spelling Speed Test is an individually administered, timed, oral spelling of a list of 40 CVC combinations. Noble, Gerrish, and Kiski (1966) found a high correlation between SST performance and rate of learning for the CVC list. The Gordon Test of Visual Imagery Control consists of 10 items in which the subjects indicate whether an automobile can be visualized in a series of changed conditions. The Mullins Imagery Scales are composed of 81 items, presented in a paired comparison format, which compare the relative vividness of six sensory based imagery dimensions. These sensory modalities are Vision, Auditory, Tactile,

Taste, Kinesthetic, and Olfaction. A 10-item End of Treatment Questionnaire was developed to assess subject reaction to using the assigned encoding method, familiarity with the method, and ease of using the method. The means, standard deviations, and range for the subjects' scores for the CTMM and SST are given in Table 3.

Three 30-word lists were constructed: a practice list, an initial learning list, and an interference learning list. The words for each list were selected from those rated on concreteness and imagery by Paivio (1968b). The practice list was composed of 16 words rated as high on concreteness and 14 words rated low on concreteness (abstract words). The initial learning and interference learning lists were each composed of 15 concrete and 15 abstract words. The practice and initial learning lists were constructed by randomly distributing approximately equal numbers of abstract and concrete words in each half of the list. Any strings of five or more adjacent words all of which were of nearly the same rated value--concrete or abstract--were broken and those words redistributed. The interference learning list was constructed by the substitution of a new word in the even numbered positions of the initial learning list. The concreteness value of each new word was approximately the same as that of the word it replaced.

Standardized instructions and materials were provided for use in conducting each of the four sessions (see Appendix A).

Procedures

Variables. The elements of the experimental design in this study are the information encoding methods used by subjects and their performance on four learning tasks. The information encoding techniques

Table 3

Descriptive Statistics of Scores on California Test of Mental Maturity (Form 5) and Speed of Spelling Test by Encoding Technique Groups

	Encoding Techniques														
	Total Sample			Repetition			Semantic Linking			Imagery Chaining			Imagery Matrix		
CTMM & SST	N = 130			N = 30			N = 30			N = 30			N = 30		
Subtests	Mean	σ	Range	Mean	σ	Range	Mean	σ	Range	Mean	σ	Range	Mean	σ	Range
Logical Reasoning	31.4	4.3	23	30.1	4.7	21	31.9	3.6	16	30.9	4.2	15	33.1	4.3	16
Numerical Reasoning	16.9	4.0	22	17	3.9	16	16.5	3.6	15	17.3	4.2	22	16.6	4.3	18
Verbal Concepts	19.4	3.6	18	19	4.1	17	19.6	3.7	14	19.7	3.4	13	19.5	3.5	13
Memory	19.2	4.0	16	18.4	4.6	16	18.9	4.4	15	20.2	3.4	14	19.5	3.7	12
Language	43.1	7.5	41	42	9.3	37	42.7	7.9	32	44.4	6.4	26	43.7	6.8	26
Non-Language	43.6	6.0	33	42.3	6.7	31	44.2	4.9	22	43.9	6.1	29	44.3	5.9	21
CTMM Total	86.9	11.7	68	84.6	14.8	62	86.9	10.6	46	88.0	10.5	48	88.4	11.0	42
SST 1	1144	211	1167	1108	214	929	1140	210	1009	1166	221	885	1153	204	897
SST 2	1086	205	1580	1079	141	60	1102	175	805	1092	206	794	1056	276	1579
Exp SST	296	48.5	224	299	49	212	293	49	224	294	47	166	293	51	209

developed for use by subjects are repetition, semantic linking, imagery chaining, and the imagery matrix (peg word) method, described previously under encoding methods. The repetition and semantic linking encoding methods are variants of the verbal encoding format. The imagery chaining and imagery matrix encoding techniques use an imagery based format which shares some perceived characteristics with visual perception and visual imagery.

The design of Experiment 1 requires measures of performance on four information processing tasks: (1) learning a 30-word list of abstract and concrete words to a criterion of one errorless replication, (2) recall of the word list after 24 hours, (3) immediately after recall, relearning the word list to one errorless repetition, and (4) immediately learning the word list again (interference learning) with a new word inserted in each alternate position of the list, to a criterion of one errorless replication.

Training and motivation. A major problem in a complex study such as this is ensuring that subjects use the assigned encoding technique on each of the learning tasks. A number of steps were taken to provide the subject with a clear understanding of the assigned encoding technique and to motivate the subject to use the technique and to practice with it until a level of competence was demonstrated. During recruitment of subjects the need to learn and use a specific learning technique was emphasized. Detailed sets of directions for training and guiding subjects in the use of each encoding technique were developed (see Appendix A). In addition the experimental assistants who trained the subjects in the use of their encoding methods and collected the performance data were instructed to query individual students on use of

the encoding method every two or three trials. Subjects were processed in small groups, ranging from one to nine students, with two research assistants present to provide a strong element of social control and rapid accomplishment of experimental tasks, i.e., checking answer sheets and running projector.

Stimulus presentation. The stimulus list was presented on a 35 mm automatic slide projector equipped with a timing device accurate to .1 seconds. The black on white stimulus image was exposed for 6 seconds with a .5-second interval between stimulus exposures. The projected image provided letters for the stimulus word approximately 150 mm in height. Subjects were seated 1.8 to 3 m from the image.

Response recording. The subjects were provided with special answer sheets with numbered spaces from 1 through 30. They were instructed to learn the stimulus by using their assigned encoding techniques during the stimulus list presentation. Immediately following the stimulus list presentation they were to replicate the stimulus list on the answer sheet, placing the stimulus words in the proper numerical position on the answer sheet. If the exact numerical position of the response was not recalled then the recalled word was placed as near to the proper numerical position as possible.

The answer sheets were collected immediately at the end of each response period and scored for correct responses. If all 30 responses were in the correct numerical position, meeting the criterion, the subject was scheduled for the next event. If the criterion of an errorless replication had not been met the subject was given additional trials until the criterion was met.

Scoring methods. The responses for each trial were scored for: (1) the number of words recalled, (2) the number of words in the correct serial position, and (3) whether each item was in the correct order in relation to the stimulus list (that it follows all words which preceded it on the stimulus list even though some of them may not have been recalled). A number of scores were generated from these data, which included: (1) the mean number of trials to criterion performance, (2) the mean number of trials to the first correct placement of an item, (3) a correct (absolute) serial position score (the total number of words in the correct numerical position, (4) a relative serial position score (the percent of recalled words in the correct numerical position), (5) an absolute orderliness score (number of words in the correct order relative to the stimulus list), and (6) a relative orderliness score (the percent of recalled words in correct order relative to the number recalled from the stimulus list). The scores derived in this manner became the basic computational units used in tests of the hypotheses.

Sequence of treatments. Subjects were required to attend four separate sessions.

The first session was used to collect demographic and learning aptitude data on the participants, to acquaint them further with the requirements of the study, to assign them an encoding method, and to schedule the future sessions. Each subject was given an "Information for the Participant" sheet to read, a "Consent of Participant" form to sign, and a "Participant Information" sheet to complete (see Appendix A). Each subject was then administered the short form of the California Test of Mental Maturity and the Spelling Speed Test (Noble et al., 1966). Each subject was assigned to one of four learning method groups and scheduled

for the remaining three sessions. Subjects were assigned to treatment groups so that the means and standard deviation for the SST scores were similar for all four groups (see Table 3).

The second session was utilized to train each subject in the use of the assigned encoding method, to provide an orientation on all experimental procedures, and to have the subject use the assigned encoding method to learn a practice stimulus list to the criterion under experimental conditions. Each subject was again given the "Information to the Participant" sheet and a description of the learning method he had been assigned. The subjects were instructed in the use of their assigned technique and allowed to ask questions. The practice stimulus list was then administered. In each trial the 30-word practice list was shown with a 6-second exposure of each word in correct serial order by use of an automatically timed slide projector. Each subject then attempted to replicate the stimulus list on his/her answer sheet. Each subject received trials until the stimulus list was learned to a criterion of perfect list replication or until 10 trials were reached. The subject was then scheduled for the next two experimental sessions.

During the third session, the first two experimental treatments were given. The subject's use of the encoding method was reviewed, questions answered, and after this warm-up period he was administered the experimental stimulus list for as many trials as was required to reach the criterion of one errorless repetition. An appointment for the next experimental session was scheduled for 24 hours later.

During the fourth session the subjects were again given both the "Information to the Participant" sheet and the description of the learning method, and the assigned method was reviewed. The subjects were then

asked to recall the stimulus list learned in the previous session and were allowed 3 minutes to complete their responses on an answer sheet. Following recall each subject was shown the stimulus list and allowed up to 10 trials to relearn the initial learning stimulus list to the original criterion. The subjects were then told that they would be shown a different list, one composed of some old words and some new words. Each subject was then given 10 trials to learn this new (interference learning) list. The subjects were then administered the Gordon Test of Visual Imagery Control, Mullins Imagery Scales, and the End of Treatment Questionnaire and released from the study.

Results

Performance Hypotheses

The measure of information processing effectiveness for the three learning tasks, initial learning, relearning, and interference learning, used in testing the first, second, and third hypotheses is the number of trials required for a criterion of perfect stimulus list replication to be satisfied. The mean number of trials to this criterion for each of the four learning methods in each of these three learning tasks is presented in Table 4. On the initial learning task, between group differences were significant, F (3,116) = 16.23, $p < .01$, and Table 4 shows the users of the matrix method learned more quickly than those who used other methods. The difference in learning rate between the imagery chaining and repetition groups was significant at the .05 level, t (116) = 2.33, $p < .05$. All F ratios are displayed in Table 10, while the occasional t-test statistics are given in the text.

A total of 11 different scoring methods were used to prepare data for analysis. Not all of the data, however, was used in this study. A complete description of scoring methods is found in Appendix B.

The relearning task was accomplished quickly, requiring only one trial on the average for all subjects. It should be pointed out, however, that one trial is not the shortest possible relearning time. If a subject demonstrated perfect delayed recall, (s)he was credited with zero trials for relearning. The small number of trials required for relearning resulted in small between group differences, which are significant at the .05 level, F (3,116) = 2.86, $p < .05$.

Table 4

Mean Number of Trials to Perfect List Replication on Three Learning Tasks by Encoding Technique
(N = 120)

Task	Encoding Technique			
	Rep	SemLink	ImagChain	Matrix
Initial Learning*	5.1	4.9	4.2	2.6
Relearning**	1.2	1.2	0.9	0.7
Interference Learning*	4.2	3.6	3.2	2.0

*Differences between groups significant at .01 level.
**Differences between groups significant at .05 level.

On the interference learning task, the between group differences were significant, $F\ (3,116) = 12.23$, $p < .01$, and the table shows the matrix method was clearly superior. The difference between the repetition and imagery chaining encoding methods was significant at the .05 level, $t\ (116) = 2.56$, $p < .05$.

The learning curves for all groups are shown in Figures 1, 2, and 3 for the initial learning, relearning, and interference learning tasks, respectively. Performance on each trial is measured by the proportion of the 30 stimulus items which were recalled in correct serial position.

Two measures were used in the evaluation of performance on the delayed recall task. The first was the number of items recalled, regardless of whether an item was recalled in its correct position. The second evaluative method measured the number of items recalled in the correct ordinal position.

This scoring dichotomy was useful for analyzing differences

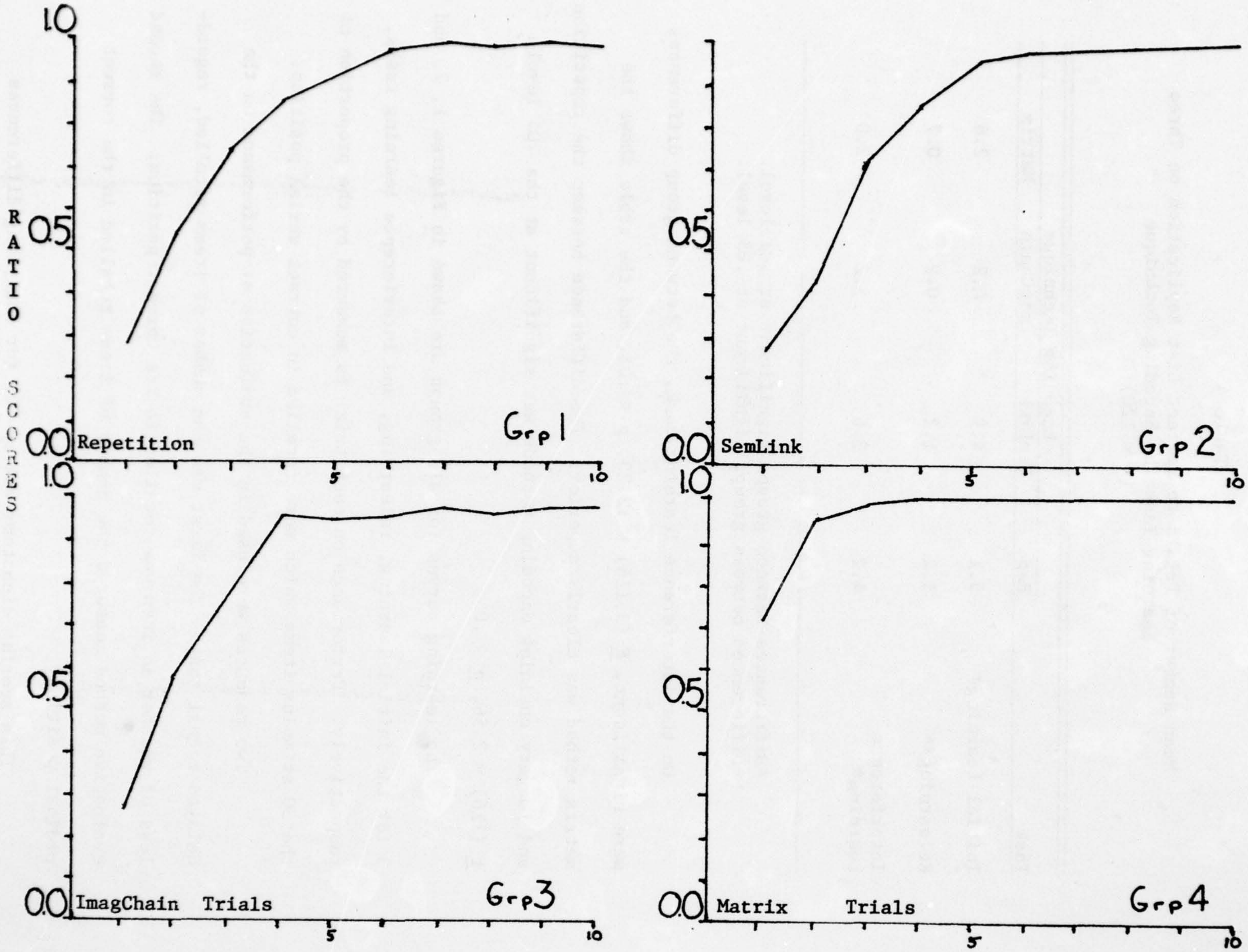

Figure 1. Initial Learning task: Ratio of mean absolute serial position scores for each trial with the maximum possible score of 30.

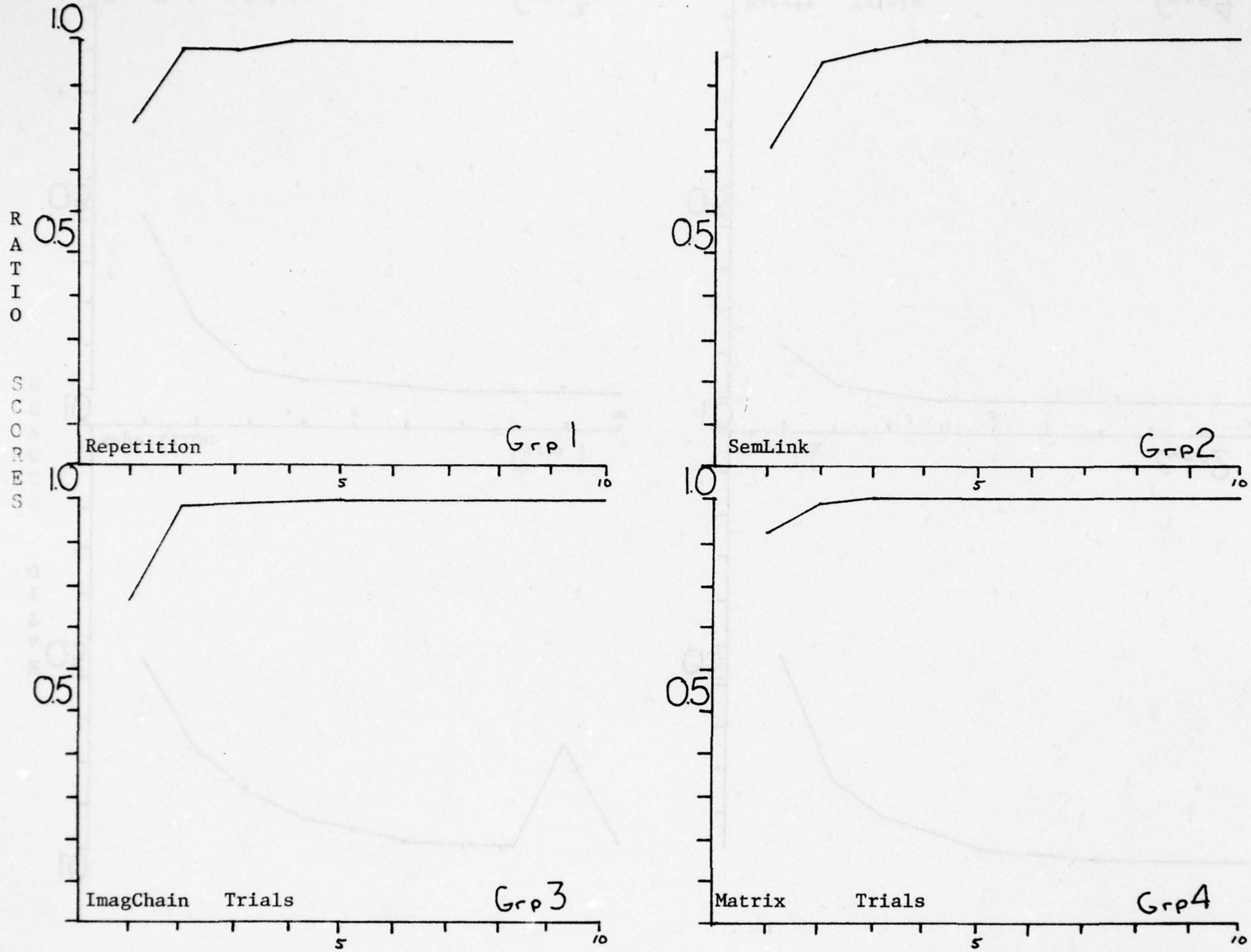

Figure 2. Relearning Task: Ratio of mean absolute serial position scores for each trial with the maximum possible score of 30.

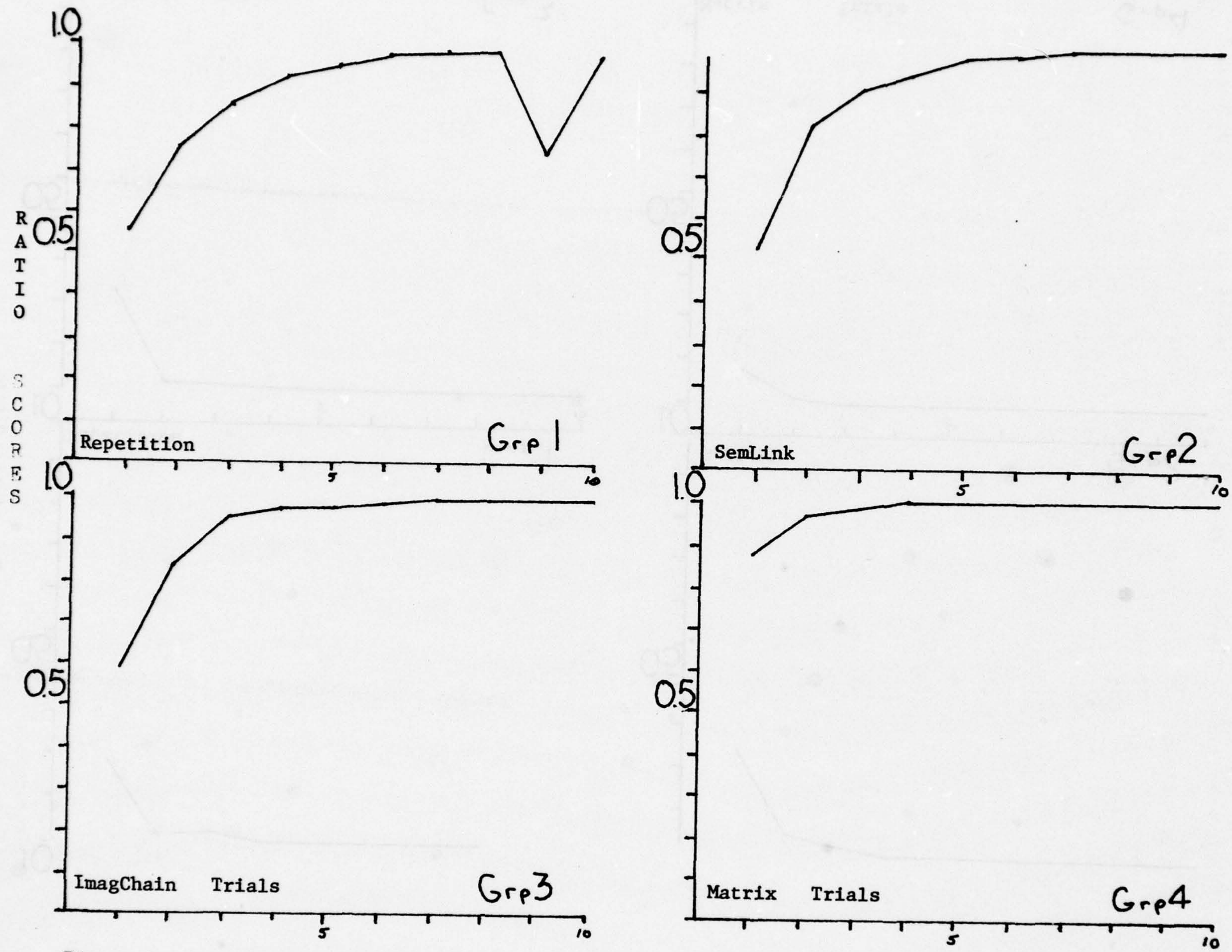

Figure 3. Interference Learning Task: Ratio of Mean absolute serial position scores for each trial with the maximum possible score of 30.

between groups. The mean number of words recalled (unordered recall) and the mean number of words recalled in correct (absolute) serial position for each learning method on the delayed recall task are given in Table 5. The between group differences were not significant on the unordered recall score. Use of the correct serial position measure, however, had between group differences that were significant, $\underline{F}$ (3,116) = 4.48, $\underline{p} < .01$, and Table 5 shows the matrix method to be the superior method. However, the difference in the correct serial position scores between the repetition and imagery matrix methods was significant at only the .05 level, $\underline{t}$ (116) = 2.33, $\underline{p} < .05$.

Table 5

Mean Number of Stimulus Items Recalled After 24-Hour Delay
($\underline{N}$ = 120)

	Encoding Technique			
Order Recalled	Rep	SemLink	ImagChain	Matrix
Unordered	26.7	27.2	27.9	27.9
Correct Serial Position*	24.2	22.8	23.0	27.8

*Differences between groups significant at the .01 level.

Learning Characteristics Hypotheses

Primacy-recency effects. The scores for the analysis of primacy and recency effects are parallel in design. For each effect two measures were constructed: one measure applies to the three learning tasks (initial learning, relearning, and interference learning) and the second measure applies to the delayed recall task. Though different, these two measures are commensurable.

To compute these measures each subject's response protocols were analyzed item by item to determine how many trials (s)he required to recall a particular item in its correct serial position. This number is the trial of first correct placement for that item.

The primacy effect measure for the three learning tasks is defined as:

$$\text{primacy ratio} = \frac{\underline{T}_{1-3}}{\underline{T}_{11-19}},$$

where $\underline{T}_{1-3}$ = average trial of first correct placement for items 1, 2, and 3, and

$\underline{T}_{11-19}$ = average trial of first correct placement for items 11 through 19.

For the delayed recall task, the primacy effect measure is defined in an analogous way as:

$$\text{primacy ratio} = \frac{\underline{P}_{11-19}}{\underline{P}_{1-3}},$$

where $\underline{P}_{1-3}$ = proportion of the first three items recalled in correct serial position, and

$\underline{P}_{11-19}$ = proportion of items 11 through 19 recalled in correct serial position.

The delayed recall measure of primacy effect is defined with the central items parameter in the numerator, rather than in the denominator as it is in the learning task measure, because the proportion of items recalled, $\underline{P}$, is inversely related to the difficulty of learning those items, whereas the trial of first correct placement, $\underline{T}$, is directly related to item difficulty.

In both cases, a primacy effect score less than unity would indicate that the initial items were easier to learn than the middle items. A score greater than unity would indicate the opposite, and a score of unity would indicate that the initial items and middle items were equally difficult to learn.

The recency effect measures are defined in a manner parallel to the primacy effect measures. For the three learning tasks we have:

$$\text{recency ratio} = \frac{\underline{T}_{27-30}}{\underline{T}_{11-19}} .$$

For the delayed recall task:

$$\text{recency ratio} = \frac{\underline{P}_{11-19}}{\underline{P}_{27-30}} .$$

In both measures the new symbols, $\underline{T}_{27-30}$ and $\underline{P}_{27-30}$, have meanings obvious in the light of the preceding discussion of primacy effect measures. The interpretation of recency effect scores is analogous to the interpretation of primacy effect scores.

The primacy effect scores and recency effect scores are displayed in Tables 6 and 7, respectively, for each of the four encoding groups and all four tasks. The primacy effect data and the recency effect data show a related item difficulty pattern: a low primacy effect score for a particular group and task is accompanied by a low corresponding recency effect score.

The matrix group showed only small primacy or recency effects on each of the four learning tasks, i.e., their primacy and recency effect scores departed only negligibly from unity. The other three encoding groups show more pronounced primacy and recency effects on the initial

Table 6

Primacy Ratios for Four Learning Tasks by Different Encoding Techniques
($\underline{N}$ = 120)

Task	Encoding Technique Rep	SemLink	ImagChain	Matrix
Initial Learning*	.40	.48	.46	.96
Recall	.86	.85	.81	.98
Relearning**	.87	.83	.76	.98
Interference Learning*	.55	.64	.66	.94

*Differences between groups significant at the .01 level.
**Differences between groups significant at the .05 level.

Table 7

Recency Ratios for Four Learning Tasks by Different Encoding Techniques
($\underline{N}$ = 30)

Task	Encoding Technique Rep	SemLink	ImagChain	Matrix
Initial Learning*	.43	.40	.57	.83
Recall	1.0	.93	.81	1.07
Relearning**	.98	.90	.83	1.05
Interference Learning**	.64	.71	.73	.92

*Differences between groups significant at the .01 level.
**Differences between groups significant at the .05 level.

learning and interference learning tasks, but generally showed only small differences from unity on the relearning tasks with the possible exception of a discernible recency effect on the relearning task for the imagery chaining group. When the primacy and recency scores for the encoding groups are compared significant differences are noted. The differences among encoding groups on primacy effect scores for the initial learning task shown in Table 6 are significant, $\underline{F}$ (3,116) = 36.61, $\underline{p} < .01$. The differences in primacy scores for the encoding groups on the relearning task are smaller than for the initial or interference learning tasks, $\underline{F}$ (3,116) = 2.74, $\underline{p} < .05$. The encoding group differences on the interference learning task for primacy effects are also significant, $\underline{F}$ (3,116) = 10.10, $\underline{p} < .01$.

Recency effects shown in Table 7 differ for the encoding groups on each task but with somewhat less departure from unity than that observed for the primacy scores. The differences among encoding groups on the initial learning tasks were significant, $\underline{F}$ (3,116) = 22.57, $\underline{p} < .01$. The differences in the recency distributions for the encoding groups on the relearning task were lower than for the initial learning task, $\underline{F}$ (3,116) = 2.90, $\underline{p} < .05$. The recency effects observed for the interference learning tasks were also lower than for the initial learning task, $\underline{F}$ (3,116) = 3.76, $\underline{p} < .05$.

Interference effects. Subjects in the interference learning tasks learned a new word list immediately after relearning the initial word list to the criterion of one errorless replication. The new word list consisted of the initially learned stimulus list with new words inserted in each even numbered, alternative position. Separate scores based on the mean trials for the first correct placement of each word

were developed for both the old and the new words in this list. The measure of the amount of learning interference caused by the substitution of a new stimulus item at each alternate position in the original list is defined as:

$$\text{interference ratio} = \frac{\bar{T}_{new}}{\bar{T}_{old}}$$

where $\bar{T}_{new}$ = mean trials for the first correct placement of the new words, and

$\bar{T}_{old}$ = mean trials for the first correct placement of the old words.

The lower this ratio, the weaker is the interference effect indicated. The mean trials to the first correct placement for the new and old words and the resulting ratios for the interference learning task are shown in Table 8. Differences among groups on the number of trials to the first correct placement of both new and old words are highly significant, $\underline{F}$ (3,116) = 10.42, and the differences among groups on the ratio scores are also significant, $\underline{F}$ (3,116) = 4.63, $\underline{p}$ < .01.

The difficulty of learning each item is shown for the four tasks (initial learning, delayed recall, relearning, and interference learning) in Figures 4, 5, 6, and 7, respectively. For the three learning tasks, item difficulty is expressed in terms of the number of trials required for first correct placement. For the recall trial, item difficulty is measured by the probability of correctly placing that item.

Table 8

Mean Number of Trials to First Correct Placement of New and Old Words, and Interference Learning Ratios by Encoding Techniques

Learning Methods	Encoding Technique: Repetition	SemLink	ImagChain	Matrix
Word Type	Trials			
New*	2.16	1.95	1.86	1.24
Old	1.47	1.46	1.38	1.03
Ratio of New to Old*	1.47	1.37	1.35	1.20

*Differences between groups significant at the .01 level.

Concrete/abstract differences. To measure the sensitivity of each encoding method to the concrete/abstract continuum for the evaluation of hypothesis five, the following ratio was defined:

$$\text{concrete/abstract ratio} = \frac{\underline{T}_{con}}{\underline{T}_{abs}},$$

where $\underline{T}_{con}$ = average trial of first correct placement for concrete items, and

$\underline{T}_{abs}$ = average trial of first correct placement for abstract items. The trial of first correct placement was computed for each item as explained above under "Primacy-recency effects."

For the delayed recall task the abstract/concrete ratio was defined as:

$$\text{abstract/concrete ratio} = \frac{\underline{P}_{abs}}{\underline{P}_{con}},$$

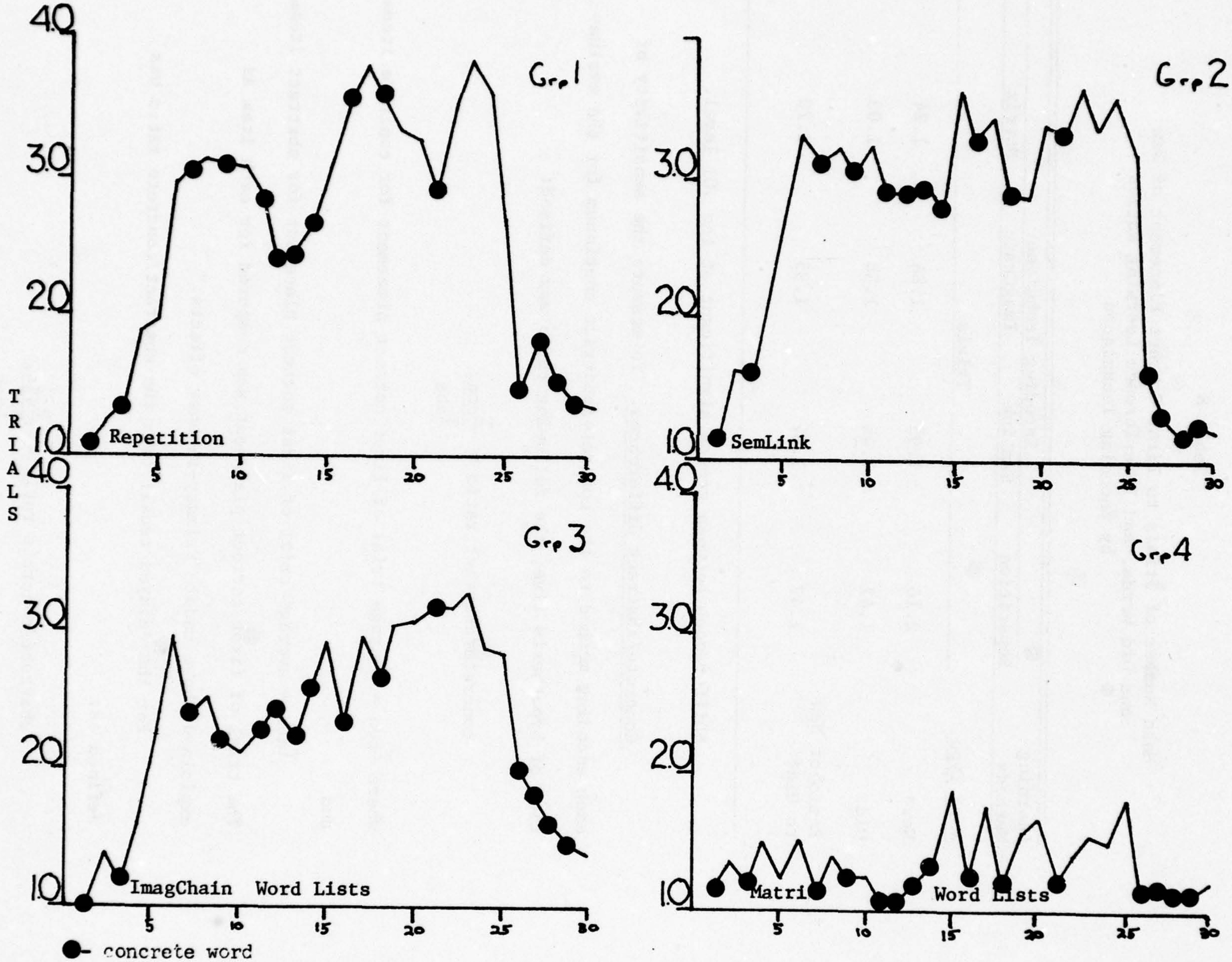

Figure 4. Initial Learning: Mean trial of first correct placement of each word.

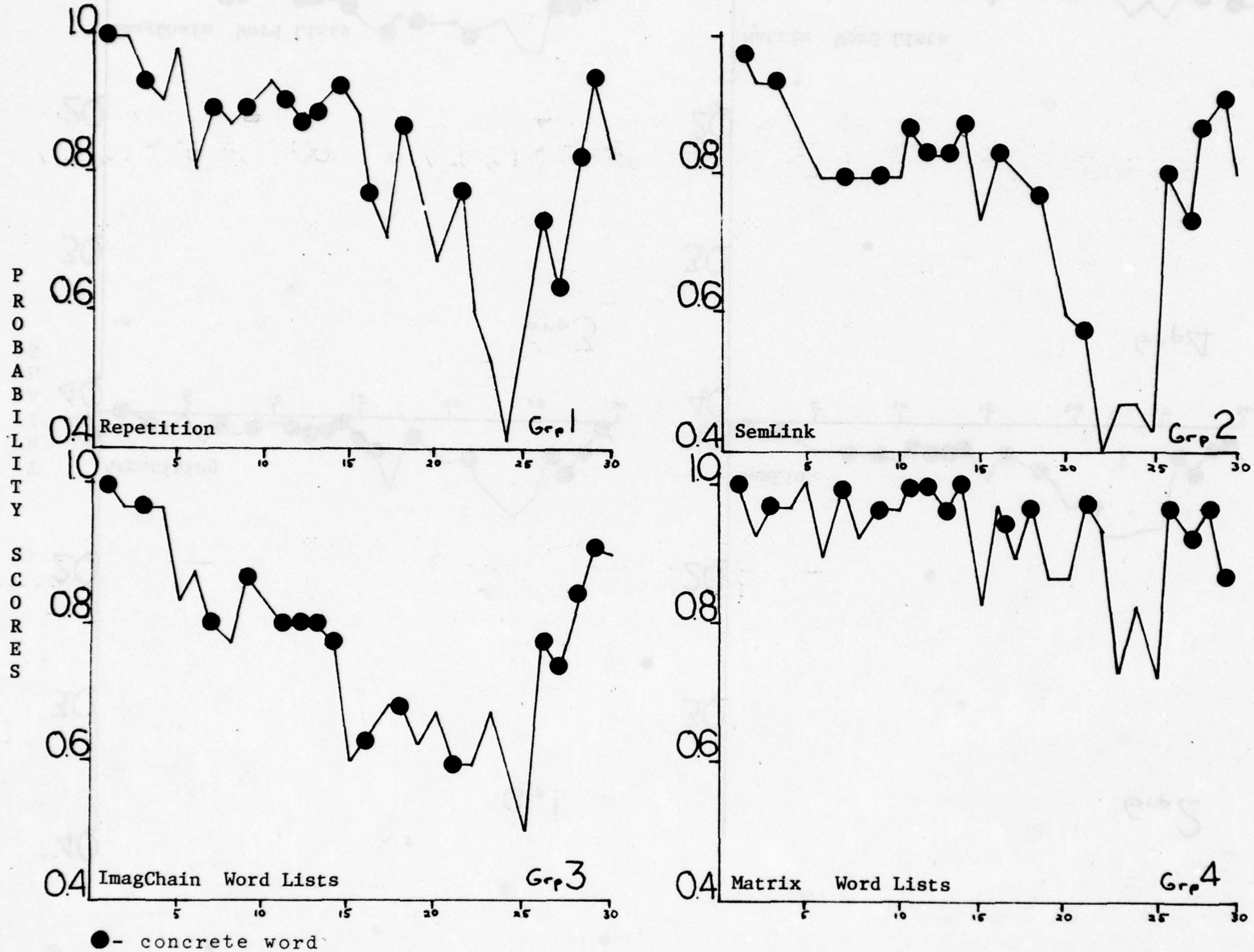

Figure 5. Recall: Probability of correct placement of each word.

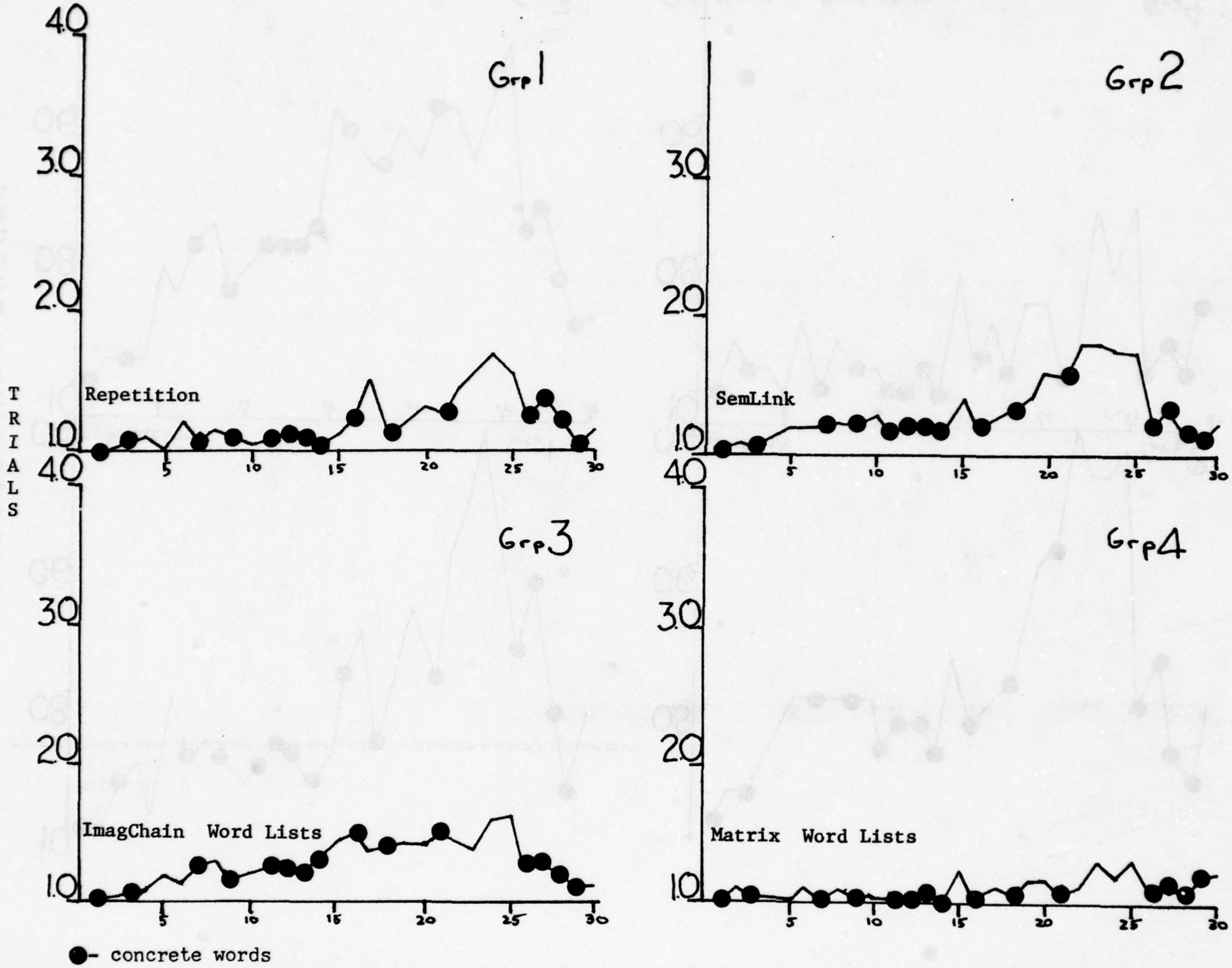

Figure 6. Relearning: Mean trial of first correct placement of each word.

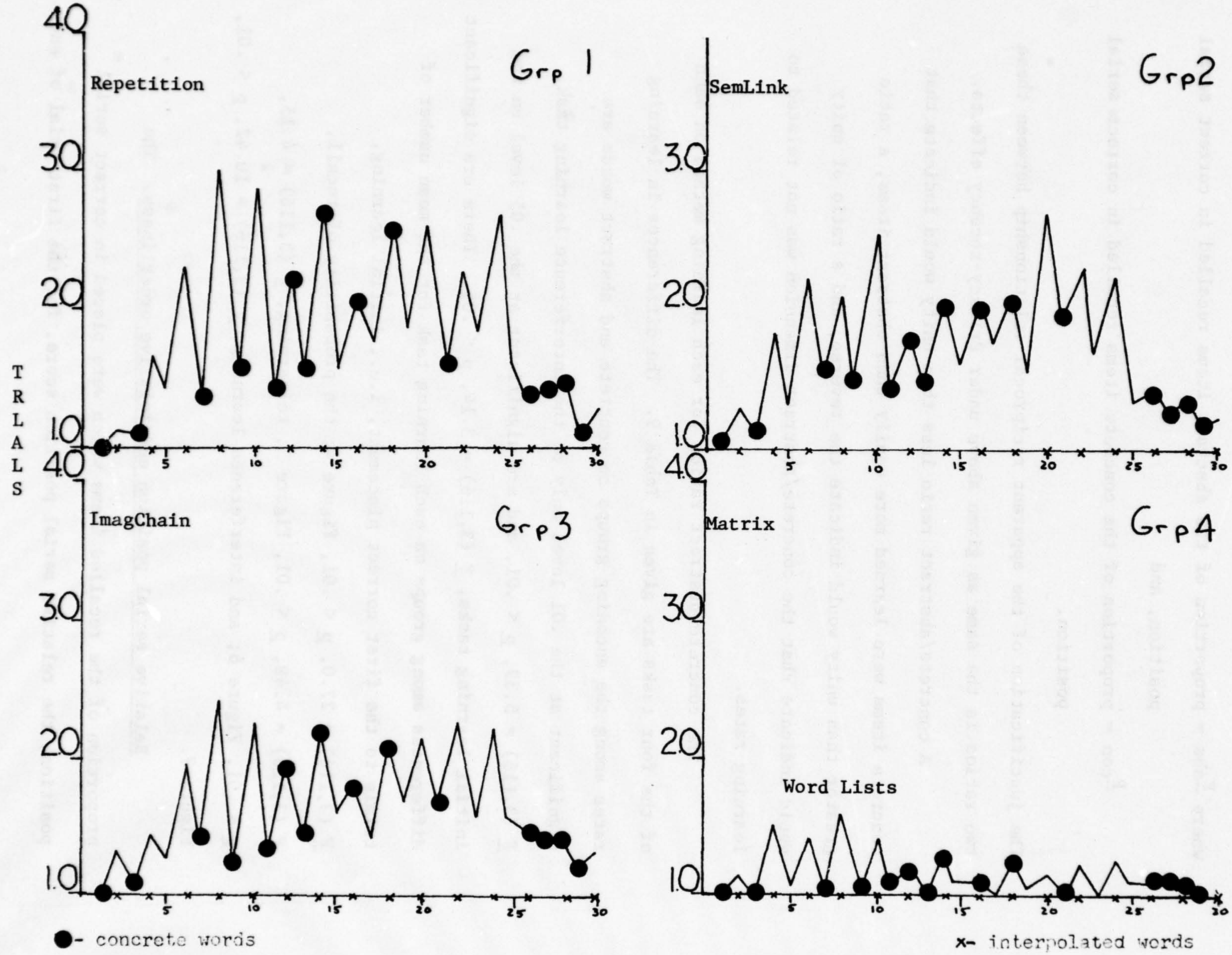

Figure 7. Interference Learning: Mean trial of first correct placement for each word.

where $\underline{P}_{abs}$ = proportion of the abstract items recalled in correct serial position, and

$\underline{P}_{con}$ = proportion of the concrete items recalled in correct serial position.

The justification of the apparent reciprocal relationship between these two ratios is the same as given above under Primacy-recency effects.

A concrete/abstract ratio less than unity would indicate that concrete items were learned more easily than abstract items, a ratio greater than unity would indicate the reverse, and a ratio of unity would indicate that the concrete/abstract dimension was not related to learning rates.

The concrete/abstract ratios for each learning method on each of the four tasks are given in Table 9. The differences in learning rates among the encoding groups on concrete and abstract words are significant at the .01 level only on the interference learning task, $\underline{F}$ (3,116) = 5.39, $\underline{p} < .01$, and are significant at the .05 level on the initial learning tasks, $\underline{F}$ (3,116) = 3.14, $\underline{p} < .05$. There are significant differences among groups on each learning task for the mean number of trials to the first correct placement, i.e., initial learning, $\underline{F}$ (3,116) = 27.0, $\underline{p} < .01$, Figure 4; the probability of recall, $\underline{F}$ (3,116) = 4.48, $\underline{p} < .01$, Figure 5; relearning, $\underline{F}$ (3,116) = 4.15, $\underline{p} < .01$, Figure 6; and interference learning, $\underline{F}$ (3,116) = 10.42, $\underline{p} < .01$, Figure 7.

<u>Relative serial position and relative orderliness</u>. The proportion of the recalled items which were placed in correct serial position, the relative serial position score, for the first trial of each

task is displayed for each group in Table 11. (Of course, the delayed recall task consists of only one trial.) The matrix method resulted in a much higher proportion of recalled items being placed in correct serial position than each of the other three methods on three of the four tasks: initial learning, delayed recall, and interference learning. Inspection of the data for the remaining three groups, repetition, semantic linking, and imagery chaining, showed no major between group differences in relative serial position scores on these tasks. On the relearn task each group correctly placed a very high proportion of those items recalled and showed very small between group differences. Figures 8, 9, and 10 show the increase in relative serial position scores over trials for each group during the initial learning, relearning, and interference learning tasks, respectively.

Table 9

Ratio of Average Number of Trials to the First Correct Placement of Concrete to Abstract Words by Learning Task for Each Encoding Group ($\underline{N}$ = 120)

	Encoding Group			
Task	Rep	SemLink	ImagChain	Matrix
Initial Learning***	0.81	0.79	0.82	0.79
Delayed Recall*	0.88	0.84	0.92	0.91
Relearning	0.90	0.86	0.95	0.92
Interference Learning**	0.81	0.84	0.88	0.90

*The entry is the ratio of proportion of concrete and abstract words recalled rather than average number of trials to first correct placement.

**Differences between ratios significant at the .01 level.

***Differences between ratios significant at the .05 level.

Table 10

F Ratios for Differences Among Encoding Groups for the Learning, Recall, Relearn, and Interference Learning Tasks, and Serial Learning, Primacy and Recency Effects, and Concrete and Abstract Words

Tasks	Source	df	Sum of Squares	Mean Squares	F Ratio	F Probability
Trials to criterion						
1. Initial Learning	Between Group	3	117.6248	39.2083	16.234	0.00
	Within Group	116	280.1672	2.4152		
	Total	119	397.7920			
2. Relearn	Between Group	3	5.0999	1.7000	2.863	0.039
	Within Group	116	68.8672	0.5937		
	Total	119	73.9670			
3. Interference Learning	Between Group	3	73.2913	24.4304	12.231	0.00
	Within Group	116	231.7007	1.9974		
	Total	119	304.9920			
4. Unordered Recall	Between Group	3	29.4375	9.8125	1.405	0.244
	Within Group	116	809.9375	6.9822		
	Total	119	839.3750			
5. Recall, Absolute Serial Position	Between Group	3	0.6426	0.1791	4.485	0.005
	Within Group	116	4.6426	.0399		
	Total	119	5.1700			
Trials to find correct placement for Primacy ratios						
6. Initial Learning	Between Group	3	4.5327	1.5109	36.615	0.00
	Within Group	116	4.7867	0.0413		
	Total	119				
7. Recall	Between Group	3	5.0899	1.6966	1.200	0.313
	Within Group	116	163.9620	1.4135		
	Total	119	169.0519			
8. Relearn	Between Group	3	0.3610	0.1203	2.741	0.046
	Within Group	116	5.0915	0.0439		
	Total	119	5.4525			

Tasks	Source	df	Sum of Squares	Mean Squares	$\underline{F}$ Ratio	$\underline{F}$ Probability
9. Interference Learning	Between Group	3	1.5088	0.5029	10.105	0.00
	Within Group	116	5.7733	0.0498		
	Total	119	7.2821			
<u>Trials to first correct placement for Recency ratios</u>						
10. Initial Learning	Between Group	3	3.7363	1.2454	22.573	0.00
	Within Group	116	6.4001	0.0552		
	Total	119	10.1364			
11. Recall	Between Group	3	4.4574	1.4858	1.443	0.233
	Within Group	116	110.4668	1.0299		
	Total	119	114.9242			
12. Relearn	Between Group	3	0.5037	0.1689	2.900	0.037
	Within Group	116	6.7156	0.0579		
	Total	119	7.2193			
13. Interference Learning	Between Group	3	.7466	0.2489	3.764	0.013
	Within Group	116	7.6697	0.0661		
	Total	119	8.4163			
<u>Ratios of trials to first correct placement for learning new and old words</u>						
14. Interference	Mean	1	590.3203	590.3203	1153.20	0.00
Learning	Groups	3	16.0088	5.3363	10.425	0.00
(Groups)	Error	116	59.3800	.5119		
(Ratios)	Mean	1	13.1902	13.1902	104.7207	0.00
Old/New	Groups	3	1.7483	0.5828	4.627	0.004
Words	Errors	116	14.6109	.1260		
<u>Ratios of trials to first correct placement for abstract and concrete words</u>						
15. Initial	Mean	1	1205.6711	1205.671	1426.2864	0.00
Learning	Groups	3	68.4830	22.827	27.0047	0.00
(Groups)	Errors	116	98.0573	0.8453		
(Ratios)	Mean	1	0.5222	0.5222	53.556	0.00
Concrete/	Groups	3	0.0388	0.0129	1.326	0.269
Abstract	Errors	116	1.1310	0.0098		

Tasks	Source	df	Sum of Squares	Mean Squares	F Ratio	F Probability
16. Recall	Mean	1	158.9703	158.9703	1989.929	0.00
(Groups)	Groups	3	1.0746	0.3582	4.484	0.005
	Errors	116	9.2669	0.0799		
(Ratios)	Mean	1	0.5222	0.5222	53.556	0.00
Concrete/	Groups	3	0.0388	0.0129	1.326	0.269
Abstract	Errors	116	1.1310	0.0098		
17. Relearn	Mean	1	355.1167	355.1167	2517.801	0.00
(Groups)	Groups	3	1.7567	0.5856	4.152	0.009
	Errors	116	16.3609	.1410		
(Ratios)	Mean	1	.8244	.8244	51.117	0.00
Concrete	Groups	3	.1156	.0385	2.389	0.072
Abstract	Errors	116	1.8707	.0161		
18. Interference	Mean	1	590.3203	590.3203	1153.202	0.00
Learning	Groups	3	16.0051	5.3350	10.422	0.00
(Groups)	Errors	116	59.3800	.5119		
(Ratios)	Mean	1	3.9170	3.9170	124.776	0.00
Concrete/	Groups	3	0.5075	0.1692	5.389	0.002
Abstract	Errors	116	3.6415	0.0314		

Table 11

Percent of Responses in Correct Serial Position on First Trial

Task	Encoding Technique Rep	SemLink	ImagChain	Matrix
Initial Learning	.63	.55	.53	.97
Delayed Recall	.90	.82	.82	1.00
Relearning	.99	.96	.97	1.00
Interference Learning	.90	.80	.84	.99

The degree to which the subjects' responses on protocol lists were correctly ordered, their relative orderliness scores, is shown in Table 12 for each group for the first trial of each task (the delayed recall task consisting of only one trial, as noted above).

Table 12

Percent of Responses in Correct Order on First Trial

Task	Encoding Technique Rep	SemLink	ImagChain	Matrix
Initial Learning	.96	.94	.94	1.00
Delayed Recall	.99	.99	.99	1.00
Relearning	1.00	1.00	1.00	1.00
Interference Learning	.99	.98	.99	1.00

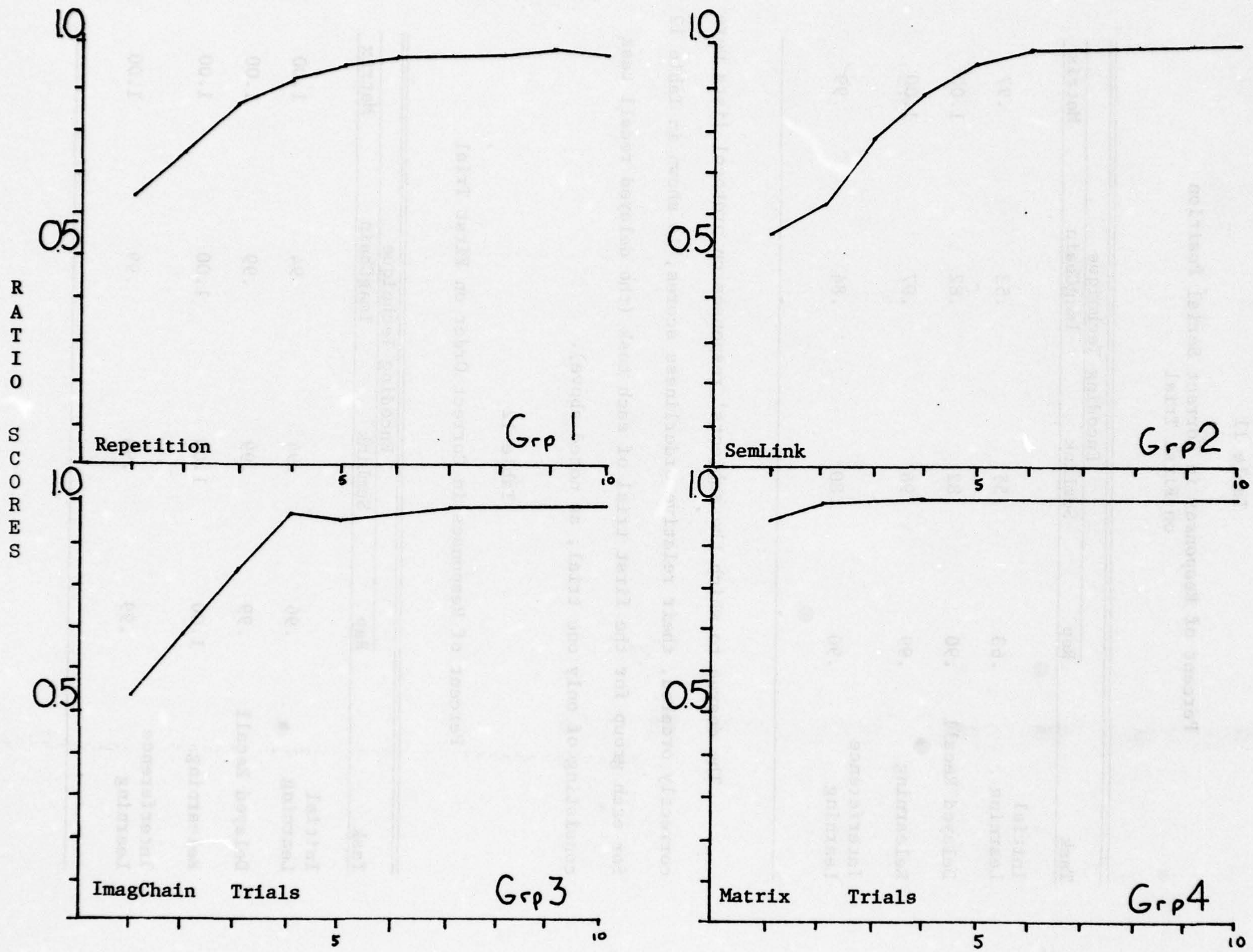

Figure 8. Initial Learning: Ratio of mean relative serial position scores with the maximum possible score of 30.

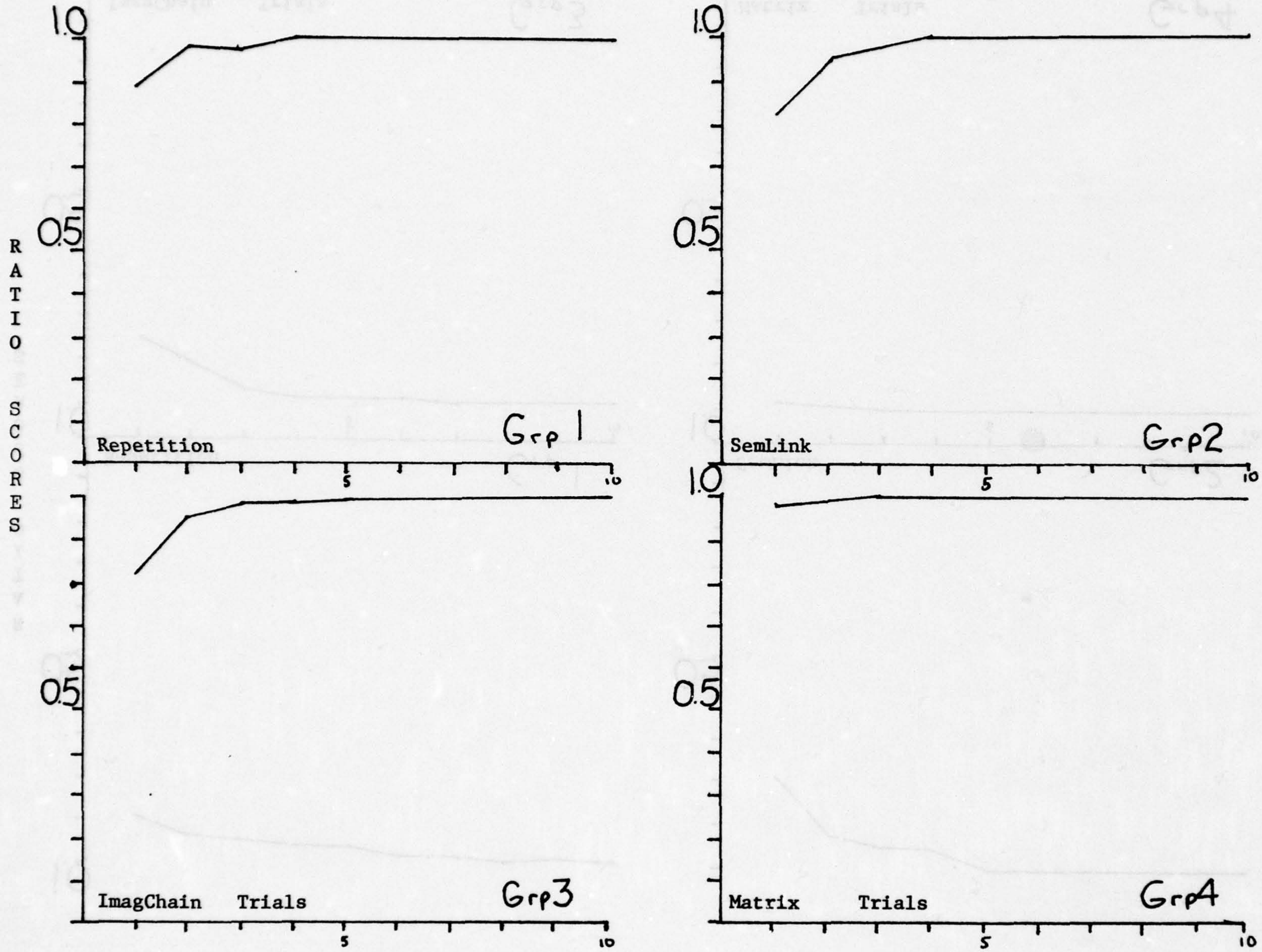

Figure 9. Relearning: Ratio of mean relative serial position scores with the maximum possible score of 30.

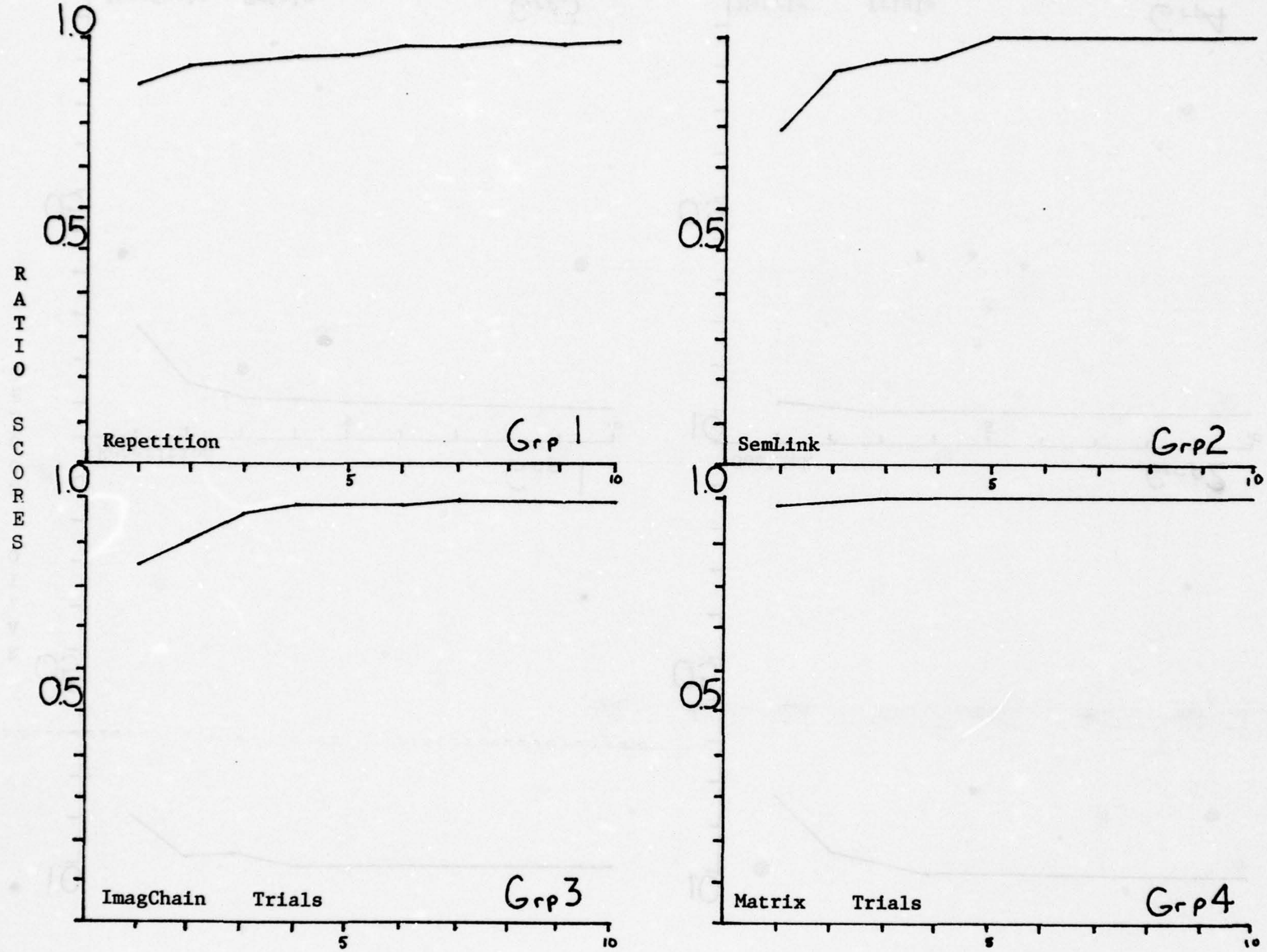

Figure 10. Interference Learning: Ratio of mean relative serial position scores with the maximum possible score of 30.

The relative orderliness scores describe the order of the subjects' responses compared with the order of words on the stimulus list. If the subject recalls 20 words, placing each in the order in which it was presented, the orderliness score is unity. If recalled words are placed out of context, either above or below their relative position to other words on the presented list, then the orderliness score is reduced accordingly. For a more thorough discussion of the difference between measuring orderliness and measuring serial position replication see the paper by Ratliff (1977) in Appendix C.

The orderliness scores displayed in Table 11 appeared quite high and a few pairs were selected for evaluation of possible significance in the difference between groups using student's $\underline{t}$ test. The difference on the initial learning task between the semantic linking and the imagery matrix groups, for example, was significant, $\underline{t}$ (59) = 42.8, $\underline{p}$ < .01. The large $\underline{t}$'s were apparently due to the small variances characteristic of these scores. A number of the differences between orderliness scores are statistically significant, but statistical significance is apparently not a practical referent in assessing differences in the orderliness of responses. The observed magnitudes of the difference in relative orderliness scores between groups and learning tasks is quite small indicating that high relative orderliness was characteristic of the first trial on the initial learning task for all four groups. Each of the four groups showed nearly perfect orderliness for the items they recalled for the remaining tasks.

Individual Differences and Performance

The data for evaluating the seventh and eighth hypotheses are

displayed in Tables 13, 14, 15, and 16. The data for evaluating these two hypotheses are correlations between measured aptitude, performance on the assigned learning tasks, and responses to imagery scales. There are a total of 20 variables from five sources: (1) the California Test of Mental Maturity (CTMM), seven variables; (2) the Speed of Spelling Test (SST), two variables; (3) the learning performance tasks, four variables; (4) the Gordon Test of Visual Imagery Control (GOTVIC), one variable; and (5) the Mullins Imagery Scales (MIS), six variables.

The CTMM variables numbered in the order in which they appear in the correlation matrix are: 1. Logical Reasoning, 2. Numerical Reasoning, 3. Verbal Reasoning, 4. Memory, 5. Language, 6. non-Language, and 7. CTMM total score. The Speed of Spelling Test provides two scores numbered variables 8 and 9. One SST score, variable 8, represents the experimental administration of the test and the other score, variable number 9, is the sum of the experimental score and the two practice scores. The learning performance task variables are: 10. Initial Learning, 11. Recall, 12. Relearning, and 13. Interference Learning. The Gordon Test of Visual Imagery Control is assigned variable number 14. The Mullins Imagery Scales contain six subscales. These are assigned as variables number 15. Visual Imagery, 16. Auditory Imagery, 17. Tactile Imagery, 18. Taste Imagery, 19. Kinesthetic Imagery, and 20. Olfaction Imagery.

Inspection of Table 13, the intercorrelation matrix for the repetition group, indicates that (1) performance on the initial learning task is significantly correlated with the Memory, Language, non-Language, and the CTMM total score, (2) the recall task scores are correlated with Numerical Reasoning, Memory, Language, non-Language, and the CTMM total

Table 13

Intercorrelations of Scores on the CTMM, the SST, the Learning Tasks, the GOTVIC, and the MIS for the Repetition Group ($\underline{N}$ = 30)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Logical Reasoning																				
2	Numerical Reasoning	.49**																			
3	Verbal Reasoning	.57**	.74**																		
4	Memory	.64**	.54**	.77**																	
5	Language	.65**	.77**	.94**	.91**																
6	Non-Language	.86**	.77**	.72**	.71**	.78**															
7	CTMM Total	.81**	.80**	.90**	.88**	.96**	.91**														
8	Exp SST	.06	.41**	.30	-.07	.17	.25	.19													
9	Comb SST	.11	.28	.10	-.22	.02	.26	.07	.78**												
10	Learn	-.15	-.28	-.22	-.42**	-.32*	-.38*	-.31*	.03	-.05											
11	Recall	-.26	-.42**	-.29	-.37*	-.36*	-.50**	-.39*	-.25	-.27	.56**										
12	Relearn	-.37*	-.48**	-.31*	-.33*	-.35*	-.63**	-.44**	-.27	-.32*	.60**	.90**									
13	Inter Learn	.04	-.30	-.25	-.24	-.24	-.34*	-.23	-.08	-.16	.71**	.39*	-.04								
14	GOTVIC	.32*	.23	.17	-.02	.14	.19	.20	.23	.28	.15	.17	.13	.24							
15	Visual Imagery	.18	.11	-.01	.01	.01	.19	.09	.21	.27	.05	-.11	-.04	.19	.02						
16	Auditory Imagery	-.03	.20	.15	.13	.13	.11	.12	.04	.07	-.25	-.11	-.06	-.16	.22	.21					
17	Tactile Imagery	.16	.14	.15	.10	.16	.12	.16	.02	-.06	.11	-.03	-.12	.04	-.13	-.44**	-.65**				
18	Taste Imagery	-.28	-.28	-.29	-.13	-.22	-.34*	-.29	-.35*	-.44**	.01	.18	.19	-.10	-.10	-.65**	-.30	.06			
19	Kinesthetic Imagery	.36*	.07	.07	-.03	-.03	.24	.14	.17	.26	.18	.07	-.07	.22	.09	.27	-.51**	.48**	-.53**		
20	Olfaction Imagery	-.41**	-.22	-.04	.07	-.09	-.35*	-.22	-.14	-.15	-.08	.02	.09	-.22	-.12	-.65**	.10	-.21	.55**	-.69**	

* .305 significant at the .05 level.
** .41 significant at the .01 level.

Table 14

Intercorrelations of Scores on the CTMM, the SST, the Learning Tasks, the GOTVIC, and the MIS for the Semantic Linking Group (N = 30)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Logical Reasoning																				
2	Numerical Reasoning	.52**																			
3	Verbal Reasoning	.30*	.29																		
4	Memory	.27	.00	.46**																	
5	Language	.43**	.33*	.85**	.82**																
6	Non-Language	.88**	.80**	.24	.11	.32*															
7	CTMM Total	.74**	.62**	.74**	.67**	.90**	.70**														
8	Exp SST	.38*	.28	.15	.32*	.32*	.37*	.41**													
9	Comb SST	.23	.13	.16	.10	.18	.19	.22	.82**												
10	Learn	.40*	-.31*	-.25	.01	-.21	-.36*	-.32*	-.47**	-.45**											
11	Recall	-.20	-.22	-.44**	-.22	-.38*	-.22	-.39*	-.18	-.07	.23										
12	Relearn	-.16	-.21	-.51**	-.18	-.42**	-.14	-.38*	-.20	-.09	.19	.89**									
13	Inter Learn	-.26	-.21	-.33*	.06	-.15	-.30	-.25	-.33*	-.40*	.50**	.44**	.40*								
14	GOTVIC	.18	-.20	-.34*	.34*	.49**	.14	.43**	.36*	.34*	-.18	-.28	-.39*	-.33*							
15	Visual Imagery	-.26	-.06	-.34*	-.16	-.30	-.14	-.29	.00	-.14	.30	.04	.03	.11	.13						
16	Auditory Imagery	.06	.11	-.27	-.01	-.18	.20	-.04	.00	-.13	-.07	-.19	-.09	.12	-.13	.24					
17	Tactile Imagery	.28	.08	.40*	-.03	-.27	.11	.25	.10	.31*	-.37*	.10	-.03	-.31*	.25	-.55**	-.67**				
18	Taste Imagery	-.04	.00	.33*	.24	.30	-.05	.20	.00	.10	-.13	.01	.11	-.19	-.02	-.71**	-.49**	.46**			
19	Kinesthetic Imagery	.19	.11	-.08	-.26	-.09	.07	-.03	-.07	-.09	.02	.06	-.13	.15	-.02	.36*	-.21	.08	-.63**		
20	Olfaction Imagery	-.06	-.17	.12	.25	.13	-.07	.06	.00	.06	.03	-.05	.07	.01	-.20	-.73**	.06	.00	.60**	-.71**	

* .305 significant at the .05 level.
** .41 significant at the .01 level.

Table 15

Intercorrelations of Scores on the CTMM, the SST, the Learning Tasks, the GOTVIC, and the MIS for the Imagery Chaining Group ($\underline{N}$ = 30)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Logical Reasoning																				
2	Numerical Reasoning	.48**																			
3	Verbal Reasoning	.23	.33*																		
4	Memory	.04	.35*	.26																	
5	Language	.27	.60**	.72**	.77**																
6	Non-Language	.90**	.74**	.25	.16	.35*															
7	CTMM Total	.68**	.82**	.63**	.57**	.84**	.86**														
8	Exp SST	.09	.26	.20	.22	.23	.19	.28													
9	Comb SST	-.04	.15	.23	.02	.12	.04	.13	.76**												
10	Learn	-.07	-.67**	-.27	-.44**	-.47**	-.37*	-.53**	-.28	-.22											
11	Recall	-.25	-.67**	-.10	-.59**	-.55**	-.40*	-.60**	-.28	-.07	.69**										
12	Relearn	-.24	-.65**	-.11	-.55**	-.48**	-.42**	-.57**	-.30	-.09	.64**	.89**									
13	Inter Learn	-.22	-.73**	-.25	-.56**	-.55**	-.49**	-.65**	-.40*	-.13	.76**	.82**	.84**								
14	GOTVIC	-.23	.09	-.27	-.34*	-.36*	-.15	-.32*	-.03	-.15	-.05	-.19	.21	.09							
15	Visual Imagery	.04	-.02	-.10	-.09	-.15	.02	-.06	.22	.23	-.01	-.05	-.06	-.09	.04						
16	Auditory Imagery	.10	.12	.24	.37*	.36*	.06	.29	.14	.24	-.16	-.32*	-.31*	-.29	-.02	.44**					
17	Tactile Imagery	-.06	-.01	-.18	.03	-.05	-.00	-.07	.02	.01	-.04	.05	-.01	.09	-.16	-.52**	-.57**				
18	Taste Imagery	-.25	-.21	-.01	-.26	-.25	-.21	-.28	-.06	-.10	.20	.32*	.32*	.32*	.06	-.53**	-.50**	.02			
19	Kinesthetic Imagery	.17	-.11	-.22	-.10	-.16	-.06	-.08	-.07	-.10	.09	.02	.03	.04	-.08	.20	-.28	.30	-.50**		
20	Olfaction Imagery	.04	.21	.24	.17	.30	.09	.24	-.15	-.19	-.13	-.13	-.10	-.13	.09	-.75**	-.09	.00	.48**	-.61**	

* .305 significant at the .05 level.
** .41 significant at the .01 level.

Table 16

Intercorrelations of Scores on the CTMM, the SST, the Learning Tasks, the GOTVIC, and the MIS for the Imagery Matrix Group ($\underline{N}$ = 30)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Logical Reasoning																				
2	Numerical Reasoning	.35*																			
3	Verbal Reasoning	.36*	.15																		
4	Memory	.34*	.02	.51**																	
5	Language	.39*	.33*	.87**	.72**																
6	Non-Language	.85**	.74**	.34*	.26	.42**															
7	CTMM Total	.73**	.60**	.74**	.63**	.84**	.82**														
8	Exp SST	-.68**	-.27	-.47**	-.38*	-.57**	-.61**	-.67**													
9	Comb SST	-.04	-.08	.01	-.14	-.13	-.16	-.16	.39*												
10	Learn	-.36*	-.13	-.16	-.46**	-.35*	-.32*	-.41**	.20	.25											
11	Recall	-.05	.13	-.31*	-.03	-.20	.03	-.09	.12	-.16	.14										
12	Relearn	.02	.31*	-.04	-.26	-.09	.19	.04	-.04	-.07	.47**	.60**									
13	Inter Learn	-.14	.19	-.20	-.26	-.22	.02	-.13	-.04	.06	.49**	.23	.32*								
14	GOTVIC	.40*	-.02	.28	.13	.16	.31*	.28	-.21	.04	-.18	-.22	-.11	-.41**							
15	Visual Imagery	-.16	-.35*	-.21	.02	-.24	-.24	-.25	.10	-.04	-.18	.19	-.08	-.29	.36*						
16	Auditory Imagery	.23	-.01	.23	.00	.07	.12	.15	-.36*	.03	.32*	.12	.30	-.12	.26	.21					
17	Tactile Imagery	-.23	.11	.04	.22	.22	-.07	.05	.24	.01	-.23	-.27	-.18	-.04	-.14	-.28	-.67**				
18	Taste Imagery	.13	.22	-.15	-.14	-.06	.16	.01	.04	.06	-.05	.01	.02	.35*	-.31*	-.69**	-.49**	.08			
19	Kinesthetic Imagery	-.42**	-.15	.01	-.02	-.03	-.32*	-.18	.34	-.07	-.07	-.22	-.23	-.35*	.01	.34*	-.19	.42**	-.58**		
20	Olfaction Imagery	.37*	.26	.17	-.02	.15	.34*	.27	-.32	.00	-.21	.05	.19	.41**	-.22	-.74**	.05	.24	.66**	.80**	

* .305 significant at the .05 level.
** .41 significant at the .01 level.

score, (3) performance on the relearning task is significantly related to Logical Reasoning, Numerical Reasoning, Verbal Reasoning, Memory, Language, non-Language, the CTMM total score, and the combined SST score, and (4) the interference learning task scores are significantly related only to the non-Language subtest at .05 level.

Inspection of Table 14, the intercorrelation matrix for the semantic linking group, indicates that (1) performance on the initial learning task is significantly correlated with the Logical Reasoning, Numerical Reasoning, non-Language, and CTMM total score, and with both the SST variables 8 and 9; (2) performance on the recall task is significantly related to the Verbal Reasoning, Language, and CTMM total score; (3) performance on relearning is significantly related to the Verbal Reasoning, Language, and total CTMM scores; and (4) performance on the interference learning task is significantly related to only the Verbal Reasoning and SST scores.

A rather pronounced pattern of correlations between learning tasks and the aptitude measures is displayed in Table 15 for the imagery chaining group. Performance on each of the four learning tasks was correlated at the .01 level with Numerical Reasoning, Memory, Language, non-Language, and the total CTMM scores, with the exception that performance on both the initial learning and recall tasks is significantly correlated at only the .05 level with the non-Language CTMM score.

The correlational data in Table 16 for the imagery matrix group present a somewhat different set of relationships between the learning tasks and the aptitude variables than is present for the other groups. Performance on the initial learning task is correlated with Logical Reasoning, Memory, Language, non-Language, and the total CTMM scores.

Performance on the recall task is related only to Verbal Reasoning, relearning is related only to Numerical reasoning, and the interference learning task is not significantly correlated with any CTMM aptitude or SST variable.

Data relating to hypothesis 8 that subjects using imagery based encoding methods would tend to have higher correlations between imagery scale scores and learning performance variables than subjects using non-imagery based encoding methods are also displayed in Tables 13 through 16. The data for the imagery scales are displayed with the GOTVIC as variable 14 and the MIS as variables 15 through 20.

Examination of Tables 13, 14, and 15 shows no significant correlations (at the .01 level) for the repetition, semantic linking, or imagery chaining groups between the imagery scales and the learning tasks variables 10, 11, 12, and 13. Inspection of Table 16, the correlations for the imagery matrix group, indicates significant correlations between the GOTVIC and Olfaction Imagery Scale and performance on the Interference Learning task. It is of interest that only two of the 112 correlations between the imagery scales and learning performance tasks are significantly correlated at the .01 level.

The End of Treatment Questionnaire

The problem of determining whether subjects use the information encoding technique prescribed by the experimenter merits serious consideration in learning research. Paivio (1969), for example, cites evidence that subjects in learning experiments may use a prescribed encoding method for one or two trials and then revert to their habitual

information processing methods. Persensky and Senter (1970b) indicated that some subjects do not use the prescribed encoding methods at all. If such a practice is widespread among experimental subjects in learning studies, then efforts should be made to determine the extent to which subjects are unable or unwilling to perform the specified encoding procedures and to take this information into account when interpreting results. In addition, there is little information available about the difficulty or amount of stress subjects encounter in attempting the use of novel methods of handling information. If the data from an experiment should demonstrate that one encoding method is more efficient than another, then it becomes important to determine to what extent this method is compatible with the established learning habits of the subject, how stressful it is to use, the relative amount of effort required in its application, whether the subject will be able to use the method in other learning situations, and how much training would be required to integrate the encoding technique into the habit pattern of the individual.

To add credibility to our analyses it was important to determine whether subjects were using the assigned encoding method. It was also necessary to estimate the difficulty they had with its use and to determine whether the chaining and matrix encoding groups responded as favorably to the use of imagery encoding as the semantic linking and repetition groups responded to the use of verbal encoding methods. To provide information on these issues a 10-item questionnaire was prepared for administration to each subject after completion of all required experimental treatments and obligations. See Appendix B for a copy of the questionnaire. The data for each item of the questionnaire are displayed in Tables 17 through 26 with significance levels for between

group differences computed from chi-square. Examination of the data shows some differences between groups which are of interest.

The first two questions address the nature of the subject's implicit response to the stimuli, whether there was a tendency to hear the stimulus or to experience it as an image. The data for Question 1 as displayed in Table 17 indicate no significant differences among groups

Table 17

Responses to Item 1 on End of Treatment Questionnaire
(N = 120)

Item 1. When a word was displayed, did you tend to mentally "hear" it as you repeated or processed it?

	yes heard all %	yes heard some %	no %
repetition	53.3	33.3	13.3
verbal linking	36.7	43.3	20.0
imagery chaining	43.3	30.0	26.7
imagery matrix	36.7	36.7	26.7

Note: n = 30 for each group.

in the tendency to hear the stimulus words displayed. One would have supposed that the verbal encoding groups would have reported more hearing responses because of the aural content of the verbal encoding directions. The tendency of the repetition group in this direction did not achieve significance. There were, however, between group differences in the perception of the stimulus word as an image. The responses to Question 2 shown in Table 18 indicate significant between group differences at the

.05 level with the imagery chaining and imagery matrix encoding groups making more positive imagery responses than those in the verbal encoding groups, χ^2 (9) = 19.1, $p < .05$. It is of interest and perhaps of theoretical significance that perception of some stimulus elements as images was reported by a majority of the subjects in each encoding group.

Table 18

Responses to Item 2 on End of Treatment Questionnaire
(N = 120)

Item 2. When a word was displayed, did you mentally see an "image" or picture the object or idea which the word represented?

	saw image for all %	saw image for some %	no image unless deliberately formed %	no image seen %
repetition	10.0	56.7	16.7	16.7
verbal linking	23.3	50.0	23.3	3.3
imagery chaining	20.0	63.3	16.7	0.0
imagery matrix	40.0	43.3	16.7	0.0

Note: n = 30 for each group. Chi-square significant at the .05 level.

This implies that subjects in all groups without regard to the encoding instructions perceived and perhaps made use of visual imagery in some way during the information acquisition process.

Three of the post treatment questions dealt with elements of task difficulty. They refer to the relative perceived ease of learning some stimulus words, the perceived difficulty of learning a list of 30 words, and the perceived difficulty of placing the stimulus words in correct

serial position. There were no significant differences among encoding groups in their responses to Question 3 (Table 19) concerning whether some of the words were easier to learn than others. When all four encoding groups are considered, 86% of the subjects' responses indicated that a "few" or "about half" of the stimulus words were easier for them to learn. Further research would be required to determine whether those words perceived as more difficult to learn were the abstract words which the data in Table 9 indicated were more difficult for all encoding groups to learn than were the concrete words.

Table 19

Responses to Item 3 on End of Treatment Questionnaire
($\underline{N}$ = 120)

Item 3. Did you find some of the words easier to learn than others?

	few easier to learn %	half easier to learn than others %	all about the same %	a few more difficult %
repetition	53.3	36.7	3.3	6.7
verbal linking	26.7	50.0	6.7	16.7
imagery chaining	33.3	60.6	0.0	6.7
imagery matrix	40.0	43.3	3.3	13.3

Note: $\underline{n}$ = 30 for each group.

The responses related to perceived task difficulty for Question 4 are tabulated in Table 20 and show between group differences significant at the .05 level. Eighty-seven percent of the imagery matrix group members rated the initial learning task as fairly easy or very easy,

χ^2 (9) = 18.3, $p < .05$. It is of interest that many members of the semantic linking group perceived the task as being more difficult than did the members of the repetition group.

Table 20

Responses to Item 4 on End of Treatment Questionnaire
($N = 120$)

Item 4. Was the task of remembering 30 words difficult for you?

	yes difficult %	yes somewhat difficult %	no it was fairly easy %	no it was easy %
repetition	3.3	33.3	50.0	13.3
verbal linking	13.3	50.0	30.0	6.7
imagery chaining	3.3	26.7	56.7	13.3
imagery matrix	3.3	10.0	66.7	20.0

Note: $n = 30$ for each group. Chi-square significant at the .05 level.

The responses to Question 5 displayed in Table 21 show a decidedly different performance experience reported by the matrix group. Ninety-six percent of them responded that the task of recalling words in the correct numerical position was not difficult, χ^2 (6) = 37, $p < .01$. The percentage of "not difficult" responses for the other three encoding groups ranged from 23% to 57%. This difference in perceived difficulty is consistent with the results of the data for the initial learning task in which the imagery matrix group subjects were able to place a greater percentage of the stimulus items in the correct serial position on the first trial than were members of the other encoding groups.

Table 21

Responses to Item 5 on End of Treatment Questionnaire
($\underline{N}$ = 120)

Item 5. Did you find it difficult to place the words in the correct serial position?

	very difficult %	somewhat difficult %	not difficult %
repetition	6.7	36.9	56.7
verbal linking	3.3	73.3	23.3
imagery chaining	3.3	40.0	56.7
imagery matrix	0.0	3.3	96.6

Note: $\underline{n}$ = 30 for each group. Chi-square significant at the .01 level.

The last five questions focus on the subject's familiarity with the assigned encoding technique, the effort involved in its use, whether the assigned technique was used during treatment, and whether the subject would use the method in school situations.

The data indicate that there were between group differences in subject familiarity with and use of their assigned encoding technique. The responses tabulated in Table 22 for Question 6 suggest that the repetition method was familiar to most of the subjects in that group, χ^2 (9) = 32.5, $\underline{p}$ < .01, but that the other encoding techniques were relatively unknown or had not been previously used by most of the subjects assigned to those encoding groups.

Table 22

Responses to Item 6 on End of Treatment Questionnaire
($\underline{N}$ = 120)

Item 6. Have you ever used your assigned learning method before participating in this study?

	yes regularly %	yes occasionally %	no but heard of it %	no & never heard of it %
repetition	6.7	60.0	13.3	20.0
verbal linking	0.0	10.3	23.3	66.7
imagery chaining	6.7	20.0	23.3	50.0
imagery matrix	3.3	10.0	33.3	53.3

Note: $\underline{n}$ = 30 for each group. Chi-square significant at the .01 level.

Between group differences in response to Question 7, concerning the level of experienced fatigue, are significant at the .01 level. These differences, displayed in Table 23, are of both pragmatic and theoretical interest. Ninety percent of the subjects using imagery encoding rated their method as not fatiguing or no more fatiguing than other methods, χ^2 (9) = 33, $\underline{p}$ < .01, while only 60% of those using verbal encoding rated their method in these two categories.

In response to Question 8 (Table 24), an inquiry as to whether they used the assigned encoding technique, most subjects in every group reported using the assigned method for all or most of the stimulus words. Only 11 of the 120 subjects, 9 of whom were assigned to verbal encoding methods, indicated that they did not use their assigned encoding method. This high proportion of compliance responses suggests that the assigned

Table 23

Responses to Item 7 on End of Treatment Questionnaire
($\underline{N}$ = 120)

Item 7. Did you find the use of the assigned learning method fatiguing?

	not at all %	somewhat but no more than other methods of study %	somewhat more than other methods of study %	yes very %
repetition	13.3	56.7	23.3	6.7
verbal linking	6.7	43.3	33.3	16.7
imagery chaining	43.3	40.0	10.0	6.7
imagery matrix	50.0	50.0	0.0	0.0

Note: $\underline{n}$ = 30 for each group. Chi-square significant at the .01 level.

Table 24

Responses to Item 8 on End of Treatment Questionnaire
($\underline{N}$ = 120)

Item 8. Did you use the assigned learning method in this study?

	yes %	mostly %	no %
repetition	36.7	50.0	13.3
verbal linking	20.0	63.3	16.7
imagery chaining	46.7	46.7	6.7
imagery matrix	56.7	43.3	0.0

Note: $\underline{n}$ = 30 for each group.

encoding method was used. Question 9 is a measure of the acceptability of each encoding method for use in other learning situations. While every encoding method used was endorsed to some extent by a majority of the students assigned to it, as shown in Table 25, in all groups except the imagery matrix some of the subjects indicated that they would not use their assigned method in other learning situations.

Table 25

Responses to Item 9 on End of Treatment Questionnaire
(N = 120)

Item 9. Would you consider using the assigned learning method in other learning situations, i.e., such as a school assignment?

	yes a lot %	yes sometimes %	maybe w/practice %	no %
repetition	20.0	46.7	13.3	20.0
verbal linking	13.3	46.7	26.7	13.3
imagery chaining	23.3	56.7	13.3	6.7
imagery matrix	16.7	63.3	20.0	0.0

Note: n = 30 for each group.

The data for Question 10, displayed in Table 26, also provide information on the subject's reaction to the assigned encoding method. Between group differences significant at the .01 level show higher self-estimates for learning rates reported by those using the imagery based encoding methods χ^2 (9) = 32.1, $p < .01$).

Table 26

Responses to Item 10 on End of Treatment Questionnaire
(N = 120)

Item 10. Did you feel that the assigned learning method helped you learn the word list faster than your own method?

	much faster w/assigned method %	somewhat faster %	about the same %	slower %
repetition	13.3	40.0	26.7	20.0
verbal linking	16.7	33.3	40.0	10.0
imagery chaining	36.7	36.7	16.7	10.0
imagery matrix	56.3	43.3	0.0	0.0

Note: n = 30 for each group. Chi-square significant at the .01 level.

Discussion

The goal of Experiment 1 is a broad, methodologically rigorous evaluation of verbally mediated and imagery based information encoding processes which are subject to a degree of individual control. It is felt that the use of some encoding methods may have the potential for improving an individual's ability to learn. The specific objectives of Experiment 1 are to: (1) compare subject manipulated encoding methods on information processing effectiveness, (2) evaluate the sensitivity of encoding methods to interference learning, primacy and recency effects in serial learning distributions, concrete-abstract stimulus properties, and the positional and ordinal accuracy of responses, and (3) determine the relationships between learning by different encoding methods, cognitive ability, and responses to imagery questionnaires.

Performance Effectiveness Hypotheses

The first three hypotheses posit differences among encoding groups in performance on the learning tasks. Differences are predicted on information acquisition rates, accuracy of recall, and resistance to interference in learning new material. In addition, the hypotheses hold that imagery based encoding methods are more effective than verbally mediated techniques, and that the sequentially cued imagery matrix technique is superior to all other encoding methods.

The data for the initial learning and interference learning tasks displayed in Table 4 show a pattern of significant differences among encoding groups. The mean trials to the criterion for the imagery matrix group are significantly lower, at the .01 level, on both the initial learning and interference learning tasks than the means for other encoding

groups. The mean trials for the imagery chaining group are significantly lower, at the .05 level, on the initial and interference learning tasks than the mean for the repetition group. These data are summarized in Table 27. The difference among means, significant at the .05 level, for the relearning task is greatest between the verbally mediated encoding techniques and that of the imagery matrix method.

The data for the delayed recall task, displayed in Table 5, for the mean correct (absolute) serial position scores show differences, significant at the .01 level, among encoding group means. The matrix method's recall scores are significantly higher than those of the other three encoding groups with no significant differences among the means of the correct serial position scores for the repetition, semantic linking, and imagery chaining encoding groups.

The interference learning task was designed to evaluate the influence of learning new stimulus material in an already learned list. The ratios of the mean trials to the first correct placement of both new and old words for each encoding group, as shown in Table 8, are used as the index of the extent of the interference during learning. The ranking of acquisition rates for the different encoding groups on the interference stimulus list shows the same ranking as that observed in Table 4 on the initial learning and interference learning tasks. The ratios for trials to the first correct placement for old and new words are significantly different at the .01 level, with the imagery matrix group being the most effective and the repetition group showing the larger ratio or most interference.

The first hypothesis, that encoding groups will vary on

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information acquisition rates, accuracy of recall, and resistance to interference is strongly supported by the significant between group differences on these learning tasks. There are significant pair-wise differences in acquisition rates between the three encoding groups using the imagery matrix, the imagery chaining, and repetition methods on the initial learning and interference learning tasks. There were no significant differences observed between the semantic linking and repetition encoding groups. The significance of the differences among encoding groups on the relearning and the recall tasks was due to the magnitude of the differences in the means between those using the matrix method and the other encoding techniques. The observed differences between the ratios on the interference learning task provide strong support for the last element of the hypothesis, that of the hierarchy for resistance to interference in learning.

The second hypothesis that the imagery based encoding methods are more effective in encoding information than the verbally mediated methods is strongly supported by the results for the initial and interference learning tasks. The imagery chaining group's mean score was significantly different from those of the repetition group, and the mean score from the imagery matrix group was significantly different from the mean of each of the other groups (see Tables 4 and 27). The mean differences among groups on the relearning and recall tasks were due to the superior performance by the imagery matrix group alone. However, the mean scores of the imagery chaining group on the relearning and recall tasks were competitive with those of the verbal mediation groups. A summary of the overall results indicates the imagery matrix method provided superior performance on every learning task. The imagery chaining group's mean scores are superior to

Table 27

Encoding Group Performance Characteristics by Learning Task for Learning Rate, Serial Distribution Effects, Concrete and Abstract Stimuli and Interference Learning

	Learning Rate			Recall		Serial Distribution Effects								Concrete/Abstract Ratios				Interference Learning		
						Primacy Ratios				Recency Ratios										
	Initial Learning	Relearning	Interference Learning	Unordered Recall	Ordered Recall	Initial Learning	Recall	Relearn	Interference Learning	Initial Learning	Recall	Relearn	Interference Learning	Initial Learning	Recall	Relearn	Interference Learning	Old Words	New Words	Ratios
F Statistic Probability	**	*	**		**	**		*	**	**		*	*	*			**	**	**	**
t for matrix v. next closest value	**	*	**		*	**			**	**		*	*							
t for chaining v. repetition	*		*							*		*	*							
t for chaining v. semantic linking										*										

*Significant at the .05 level.
**Significant at the .01 level.

that of the repetition group on the initial and interference learning tasks and are similar to those of the repetition and semantic linking groups on the relearning and recall tasks. These results may be interpreted as providing strong support for the hypothesis that imagery based encoding methods are superior to the verbally mediated information processing techniques.

Discussion of the third hypothesis, that the imagery matrix encoding technique is superior to other encoding techniques appears redundant. The group using the imagery matrix method demonstrated superior performance on each learning task considered.

Learning Characteristics Hypotheses

The fourth hypothesis postulates a hierarchy of vulnerability to two types of associative interference: a primacy/recency effect and interference due to the substitution of new stimulus material. The interference effects of learning new material in an already learned list were discussed under the first hypothesis. The predicted hierarchy of vulnerability to primacy-recency effects is only partially realized. The data, in Tables 6 and 7, provide support for the contention, however, that there are differences in sensitivity among learning strategies to the serial learning primacy and recency effects.

The differences among encoding groups on primacy effect in Table 5 are significant at the .01 level on the initial and interference learning tasks and at the .05 level on the relearning task. The between group differences on the recency effect (Table 7) are significant at the .01 level on the initial learning task and at the .05 level on relearning and interference learning tasks.

The predicted hierarchy of primacy and recency ratios did not emerge in general on these learning tasks, except as a large difference in the size of the ratios between the group using the matrix method and the other encoding groups.

McCrary and Hunter (1953) indicated that primacy and recency effects resulting from serial learning were strongly influenced by the level of mastery of the list. They showed that a plot of the percent of total errors made for each position in a learned list under different levels of mastery would reproduce a serial effects learning curve of approximately the same depth and shape as the original curve on the first trial. The mean trials to the first correct placement are plotted for each encoding group on each trial in Figures, 4, 5, 6, and 7.

These data show differences in the shape of the learning curve, such as depth and breadth, for each encoding group. The mastery level achieved by the matrix group is clearly apparent on the initial and interference learning tasks. However, despite the flattened curve and the higher level of mastery for the matrix group, the errors during learning of the list appear to have been made in the same stimulus positions as those made by other encoding groups. Thus a percentage of total error analysis for different positions on the stimulus list would probably show approximately the same curve as would data plotted for the repetition or semantic linking encoding groups. The use of ratios in Tables 6 and 7 based on the mean trials to the first correct placement of stimulus words as a method of indicating primacy and recency effects is probably more sensitive to the mastery level of the stimulus list than to the shape of serial distribution curves.

The fifth hypothesis states that use of the imagery based encoding

methods will show larger differences in acquisition rates for concrete and abstract words than use of verbally mediated encoding methods. The data in Table 9 are ratios for the mean trials to the first correct placement of each concrete and each abstract word on the four learning tasks. There are significant differences among ratios on two learning tasks, the initial learning and the interference learning tasks. The differences among abstract/concrete ratios for the initial learning task are significant at the .05 level. However, there is no discernible pattern of differences between the imagery based and verbally mediated encoding methods. The differences among abstract/concrete ratios for the interference learning task are significant at the .01 level. There is a pattern of differences among ratios on this learning task, but they are counter to that stated in the hypothesis. That is, the imagery based encoding methods appear less sensitive to differences in the abstract/concrete continuum than the verbal encoding methods. In fact, these data on the interference task indicate that the use of an imagery encoding method is more efficient in the encoding of abstract words, relative to the encoding of concrete words than the verbal encoding method. The hypothesis as stated is not supported by the data. A statement of a counter hypothesis that imagery encoding is relatively more effective with abstract words than verbal mediation would provide a more appropriate fit for the data displayed on the interference learning task.

The sixth hypothesis states that a hierarchy of encoding groups would form on the orderliness and correct serial positioning of stimulus list responses. The assumed ranking of the groups from the least accurate to the most accurate is repetition, semantic linking, imagery chaining, and the imagery matrix groups.

The initial assumption was that encoding groups would differ to an observable degree on the ordering of responses, and to a greater degree on the accuracy of positioning of responses. It was thought that the ordering of responses would increase rapidly on the second trial and with noted improvement in the positioning responses.

The data in Table 12 show that relative orderliness (the extent to which the order of the stimulus list is replicated in the obtained responses) is quite high for all learning tasks and encoding groups with little indication of an emerging hierarchy as predicted. The only apparent departure from unity is on the initial learning task, and there is no indication of the predicted hierarchy there except for the very high orderliness of responses for the matrix group. The high level of orderliness observed in the responses of all four encoding groups is consistent with the results reported by Detterman and Brown (1974) in which a high level of order information retention was reported for both recall and serial learning conditions.

The conclusions which appear reasonable from these data are that a high level of orderliness information is retained from a single presentation of the stimulus by all encoding groups and that the two imagery methods as a group, did not appear to provide higher levels of orderliness than did the verbal mediation groups.

The data in Table 11 on the relative serial position responses, the proportion of the reproduced responses placed in the correct serial position and shown for all trials in Figures 8, 9, and 10, do not show a tendency towards a hierarchy, except for the much higher proportion of correct serial position placement by the matrix encoding group. It is apparent the imagery chaining group did not produce more accurate

positioning responses than the verbal mediation groups. The data presented in Tables 11 and 12 do not provide convincing support for the sixth hypothesis.

Aptitude, Learning, and Imagery Responses

The correlational data displayed in Tables 13, 14, 15, and 16 address hypotheses 7 and 8, that each encoding group will have the same general level of correlation between measured aptitude and learning tasks, and that the groups using the imagery encoding method will show positive, significant correlations between learning performance and imagery scale scores. These data are summarized in Table 28 for convenient reference.

In general, the more common relationship between aptitude measures and learning performance is that the intellectually demanding tasks have a higher correlation with selected aptitude variables than the less complex tasks. However, the intercorrelation matrix for the repetition encoding group in Table 12 shows that the relearning task has more significant correlations with CTMM aptitude subtests than the initial learning or the interference learning tasks. The data for trials to criterion for the relearning task in Table 4 indicate fewer trials to the criterion than for the initial learning or the interference learning tasks and thus is an easier task. One would expect less useful variance and lower correlations with any given aptitude variables for this task than for the more demanding tasks. The intercorrelations between the CTMM subtests appear to be in the range expected on aptitude tests and are sufficiently high to indicate stability in the measurement process within this encoding group. Therefore, the observed correlations appear to represent a reliable measure, and no rationale for this apparent deviation

Table 28

Significance of Correlations Between Aptitudes, Imagery Scales, and Learning Performance by Encoding Group (N = 130)

Encoding Groups	Learning Tasks	Logistical Reasoning 1	Numerical Reasoning 2	Verbal Reasoning 3	Memory 4	Language 5	Non-Language 6	CTMM Total 7	Exp SST 8	Comb SST 9	GOTVIC 10	Visual 11	Auditory 12	Tactile 13	Taste 14	Kinesthetic 15	Olfaction 16
Repetition	Init. Learn				**	*	*	*									
	Recall		**		*	*	**	*									
	Relearn	*	**	*	*	*	**	**		*							
	Interference						*										
Semantic Linking	Init. Learn	*	*				*	*	**	**				*			
	Recall			**		*		*									
	Relearn			**		**		*			*						
	Interference			*					*	*	*			*			
Imagery Linking	Init. Learn		**		**	**	*	**									
	Recall		**		**	**	*	**					*		*		
	Relearn		**		**	**	**	**					*		*		
	Interference		**		**	**	**	**	*						*		
Imagery Matrix	Init. Learn	*			**	*	*	**					*				
	Recall			*													
	Relearn		*														
	Interference										**					*	**

*Significant at the .05 level.
**Significant at the .01 level.

in relationships for the repetition group is obvious from examination of the data.

The data in Table 14 for the semantic linking group show fewer significant correlations between learning performance tasks and aptitude variables than was evident for the repetition group in Table 13. Two of the three correlations significant at the .01 level are between the relearning task and aptitude variables. Thus some parallel with the pattern of correlations between learning performance and aptitude variables in the repetition group is observed.

The lack of the expected number of relationships between verbal learning performance by the semantic linking group and aptitude variables suggests that use of verbal linking on serial learning tasks may not organize or focus the cognitive functions to the extent this occurs on more complex learning tasks or with the use of other encoding methods.

In contrast to the few correlations observed between learning performance and aptitude in Tables 13 and 14 for the repetition and semantic linking groups, the imagery chaining group shows significant correlations in Table 15 between all learning tasks and the aptitude variables of numerical reasoning, memory, language and non-language, and CTMM total score. These correlations are significant at the .01 level except for the correlations between the non-language variable and the initial learning and recall tasks which are significant at the .05 level. This pattern of correlations which encompasses all tasks and five aptitude variables, when compared with the much different pattern of correlations from the other encoding groups, suggests that a range of intellectual abilities are being tapped by the ideational manipulations required in applying this encoding method. It further suggests that the ideational mechanisms are activated in much the same

way for each task. There appears to be little difference in the intellectual faculties tapped between initial learning, recall, relearning, or interference learning for example.

Table 16 shows fewer significant correlations between performance tasks and aptitude variables for the imagery matrix group than for any other encoding group. The correlations for the initial learning task and the memory and CTMM total score are significant at the .01 level, and there are only two significant correlations among the other learning tasks. The most probable reason for the low number of correlations, particularly in view of the number of positive correlations with the Armed Services Vocational Aptitude Battery subtests in Experiment 2, is the lack of variance remaining after the initial learning task was accomplished. Learning a 30-word list represents, in the author's experience, an easy task for a user of the imagery matrix method.

The correlational data for the encoding groups with the exception of that for the imagery chaining group provide little support for the seventh hypothesis.

The eighth hypothesis predicts significant correlations between learning performance of the imagery based encoding groups and their scores on the imagery scales. Significant correlations between the GOTVIC, the MIS, and the aptitude measures occur at a rate which closely approximates chance, and there is no replication of correlation patterns from one group to another. The lack of significant correlations between the imagery scales, aptitudes, and learning performance suggests that the imagery encoding training administered as a part of this study was not sufficient to change the normal pattern of imagery responses on these scales for the members of the imagery chaining and the imagery matrix

groups. The conclusion is clear, the eighth hypothesis is not supported by these data.

End of Treatment Questionnaire

The end of treatment questionnaire was designed to obtain information from the subjects on their reaction to the stimulus list, the encoding method used, perceived effort required to learn, and other parameters that may be useful in evaluation of the data for each encoding method. The responses to the end of treatment questionnaire added a useful and perhaps a unique dimension to the assessments made in this study and provided perspective on encoding methods which may have application in the development of an instructional technology.

The results of the questionnaire indicate that a majority of the population would find an imagery based or mnemonic programming instructional methodology an acceptable learning method, compatible with their encoding set, and easy to learn to use. This conclusion is based on responses that a majority of the subjects experience verbally presented stimuli as both sound and image, that the imagery based encoding methods were rated as making the learning task easier than with their own method, and that imagery based methods were rated as not being fatiguing.

The interpretation of survey data is often equivocal, depending upon a number of variables; however, the evidence is convincing that the use of an imagery based encoding method was favorably received by a majority of subjects assigned to those groups.

Evaluation

The comparison of imagery based and verbally mediated encoding methods on performance effectiveness, response characteristics, and the

relationships between learning performance, aptitude, and imagery scale responses produced significant differences that are attributable to the use of different encoding techniques. The basic contention that the imagery based encoding methods and the imagery matrix method in particular are superior information encoding methods is strongly supported by the data from the learning tasks. The imagery matrix method was clearly superior (see Table 27) to the other encoding methods on acquisition rate, recall, accommodation to learning new material, encoding of abstract and concrete stimuli, and in the positional accuracy of responses. The superior acquisition rate attained by the imagery matrix method provides support for results reported by Smith and Noble (1965), Bugelski, Kid, and Segmen (1968), Kulhavey and Heinin (1974), and Lowry (1974).

The imagery chaining method is superior to the repetition method on acquisition rate for the initial learning and the interference learning tasks and is nearly as effective as the matrix method on encoding abstract stimuli. The response characteristics from the use of the imagery chaining method on the recall and relearning tasks were similar to those obtained for the repetition and semantic linking groups. In general the imagery chaining response characteristics appeared to resemble those of the verbally mediated encoding groups more than those of the imagery matrix group. Inspection of the data for the absolute serial position scores for each encoding group in Figures 1, 2, and 3 show the acquisition curve for the imagery chaining group as parallel to those of the verbal mediation groups. This level of similarity appears to hold for the mean trials to the first correct placement in Figures 4, 5, and 6 and for the relative serial position scores in Figures 8, 9, and 10. The imagery chaining group appears somewhat more robust than the

verbal encoding groups in each set of figures, but this apparent advantage has little influence on the shape of the learning curves.

The data for the imagery chaining method showing superior encoding effectiveness on the initial learning and interference learning task are in agreement with the findings reported by Bugelski (1974) that imagery is more effective in serial processing than verbal mediation. The imagery based encoding methods had the lowest ratios on the interference learning task for the first correct placement of the new words in the list. This result is of significant theoretical interest as the imagery chaining group which ranked second to the imagery matrix method in overcoming the effects of interpolated material presumably relies upon a different figure-ground relationship between images than that used by the matrix group for imagery storage and retrieval. The imagery matrix method utilized a fixed alphanumeric link between each location for storage of a stimulus image, whereas the imagery chaining method used each new stimulus image to overlap a previously formed stimulus image. The overlap of one stimulus image over another provides a sequence of images in which each adjacent image must be recognized and traced to the next overlapping image to be recognized for recall. A loss of a single image may result in a break and a loss of the rest of the chain. It would seem, under these circumstances, that inserting a new word (image) into each alternate stimulus position would be extremely disrupting to the imagery chaining process. The learning of new material in each alternate imaginal link in the chain, at a more rapid rate than that of the verbal learning groups, suggests that imaginal associations have strong, labile properties.

Examination of the data in Figures 1, 2, and 3 for the development

of absolute serial position scores (the mean number of words in the correct serial position on each trial), indicates that the imagery matrix group has a much flatter acquisition curve than the other encoding groups. The shape of this curve for the imagery matrix group indicates a more rapid acquisition rate and stronger positional integrity of the recalled responses. The same differences in the shape of the curves are seen in Figures 8, 9, and 10 for the relative serial position scores for each group (the percent of the recalled responses in the correct serial position). Those using the imagery matrix recalled approximately 70% of the stimulus list on the first trial (Figure 1) and of these, 95% were in the correct serial position (Figure 9). These are much higher scores in both categories than were achieved by the other encoding groups.

The two scores generated on the recall task, unordered recall scores and the correct serial position recall scores, further illustrates the strong positional attachments of the imaginal bonds over time. The mean unordered recall scores for all four encoding groups are quite similar. Yet when the correct serial position scores are used as the criterion, the matrix group's mean score loss is .1 of a word and the mean loss for the other three encoding groups is 3.9 words per group. These results for the delayed recall task, using the mean absolute serial position scores as the criterion, in which the matrix group outperforms the other encoding groups, differs from those reported by Kulhavey and Heinen (1974) and Lowry (1974) in which they found no differences in delayed recall among groups. The lack of between group differences on the unordered recall scores is consistent with the results reported by Underwood (1954b) in which equivalent rates of forgetting were associated with equivalent levels of associative strength achieved during learning,

unless losing a positional referent is considered as initial phase of the forgetting process.

The role of the positional associations in information acquisition in this context appears to be an important concomitant of the matrix encoding method. Strong positional associations observed with the use of the matrix method have been reported by Bower (1970), Bugelski (1968), and Wood (1967). However, influence of associative strength concept on recall rates may require some additional interpretation to reflect the differences between the mean unordered recall scores for the non-matrix encoding groups and their absolute serial position scores. Detterman and Brown (1974) reported a series of three experiments comparing serial learning and free recall from which they concluded that (1) the retention of item information is unaffected by the retention of order information, and that (2) increases in item retention are a function of total study time for the list, and increases in order retention are a function of study time per item. Bahrick (1965) describes recall data based on the number of trials as an equivocal measure of associative strength. When a number of trials are given for either paired associate or serial learning, associative strength for a number of the items will vary on a continuum as a function of unequal learning rates. On recall, associative strength will be distributed about the recall threshold with some items in an indeterminate state, as to whether they will be recalled or not. In addition, confounding factors and artifacts may influence the final state for some of these items. Acceptance of these presumptions that (1) there is a lack of a direct effect between retention of item and order information, (2) the allocation of study time affects whether items or order is emphasized in

retention, and (3) there are indeterminate item association values in the area of the recall threshold, leads one to expect differences between unordered recall and absolute serial position scores on a delayed recall task.

Acceptance of the conditions described above assumes that associative bonds to a list are established, over trials, to both adjacent and nearby words. During the delay period these inter-item associations weaken, and the item becomes less strongly bonded to both its position and the list. Apparently the associations with the list position weaken such that the item drops from a specific position before it passes below the threshold of recall, accounting for the differences between ordered and unordered recall. The data in Figure 8 show the reverse of this process on the initial learning task. Approximately 40% of those words recalled on the first trial by the three non-matrix groups are not in the correct serial position; however, the percentage of the words recalled in the correct serial position increase rapidly with each trial. This model of progressively stronger positional association suggests that the process by which words become attached to a specific ordinal position is through the establishment of associations with the list, and then with the position.

The imagery matrix system on the other hand, uses prelearned alphanumerically linked locations as storage for stimulus images. When the stimulus image is stored in a figure-ground relationship within one of the designated locations it has no bonds with any other stimulus item in the list as a part of the encoding process. The bonds established between the stimulus image and the assigned position apparently incorporate the associative strength equivalent to that developed over trials

in serial learning between a stimulus item and the adjacent and nearby words.

The data in Table 5 show that unordered recall for the four encoding systems are very similar, indicating that words drop below the recall threshold at the same rate for each method. The differences in correct serial position scores rated between the groups suggest that the imagery matrix position bonding are much stronger than those achieved through serial learning. The data indicate that all of the matrix methods associations are developed for the position, and that the total associative strength is equivalent to that established through serial learning processes.

When groups are compared on a criterion it is often useful to assess the range of differences among them as well as determining the level of statistical significance. The difference in ranges between means reported from other studies for groups using an imagery based mnemonic technique compared with those using other encoding methods is often quite small (Lowry, 1974; Persensky & Senter, 1968; Smith & Noble, 1965; Wood, 1967). The data in Table 4 for learning serial word lists indicate the acquisition rate using an imagery based mnemonic is twice that using the repetition encoding method, a greater difference than reported in the above studies. This difference is comparable to those suggested as possible by Bower (1970) and reported by Bugelski (1968). Many of the reported studies differ in the amount of training given to subjects, the mnemotechnic used, exposure time per item, and on other experimental design elements to the extent that only a crude comparison for learning rates between studies can be made. However, the differences reported here for both the initial learning and interference tasks

represent a high level of encoding effectiveness if these results generalize to other learning contexts and situations. Gains in learning rate of the magnitude observed as a product of the encoding method used suggest a potential for augmenting the learning process.

The failure of the data to support the fifth hypothesis that imagery based mediation would show greater differences on the encoding of abstract/concrete stimuli than verbal mediation provides one of the more significant developments in this study. Bower (1970) and Paivio (1969) hypothesized that the abstract/concrete continuum would influence the codibility of stimuli, according to the mediating method employed. Abstractions were thought to be more easily encoded with the use of verbal mediation, and concrete stimuli were encoded more rapidly with the use of imagery based methods. The theoretical structure erected on this presumption posed a number of limiting circumstances and defined a set of restraints upon the potential use of imagery as an information processing medium.

Bugelski (1970) advanced the position that imagery was a basic element in ideation, that most thinking was based on more concrete symbology than was previously considered. He maintained that abstract concepts could be encoded through use of symbolic representation as effectively as concrete items. However, the supposed strength of the abstract/concrete continuum limited the development and exploitation of Bugelski's ideas.

The data presented here do not show that abstract words are more effectively encoded by use of verbal mediation than by imagery based encoding. There are no apparent differences between the verbal and imagery based methods on the initial learning task. The differences

shown on the interference learning task tend to favor imagery encoding for abstract words as being more effective than verbal encoding. Should these results regarding the abstract continuum be supported in subsequent research, the potential role of imagery in intellective functioning and encoding information would be greatly expanded and perhaps make possible new perspectives on intellectual functioning and learning.

EXPERIMENT 2

Method

Subjects

All subjects were male airmen in four basic training flights at Lackland Air Force Base, San Antonio, Texas. The subjects, who were in their 5th-9th days of training, were instructed in separate classes composed of one basic training flight of approximately 40 members. Two training flights were arbitrarily chosen for the experimental group and the other two for the control group. Flight members were not excused from their various duty details and many subjects were unable to complete the full schedule of training. Attendance at all five training and testing sessions was the sole requirement for the acceptance of a subject's data. The experimental group consisted of 61 valid subjects, and the control group had 65 valid subjects.

Biographical and aptitude data consisting of age, years of formal education, a mental category score on the Air Force Qualifications Test (AFQT), and the four aptitude indices of the Armed Services Vocational Aptitude Battery - Form 3 (ASVAB-3): Mechanical, Administrative, General, and Electronics, were collected for each subject. Table 29 shows the biographical data for the experimental and control subjects. There are no significant ($p < .05$) between group differences in this background data.

Subgroups Based on Performance and AFQT Scores

Subjects were divided into subgroups within both the experimental and control groups for further analysis depending upon their ranking on

Table 29

Demographic and Aptitude Characteristics of Sample

($\underline{N}$ = 126)

	Total			Experimental Group*			Control Group**		
	Mean	σ	Range	Mean	σ	Range	Mean	σ	Range
Education	12.1	0.6	3	12.1	0.4	3	12.2	0.8	3
Age	19.3	1.7	8	19.1	1.5	8	19.4	1.8	7
AFQT	62.0	6.2	68	61.0	5.7	63	63.6	16.5	63
ASVAB									
Mechanics	61.7	20.6	80	62.5	19.9	80	61.1	21.3	80
Administrative	52.5	17.2	80	53.5	17.2	75	61.6	17.2	80
General	66.4	15.7	60	65.6	15.7	60	67.2	15.8	50
Electronic	67.3	16.9	65	66.6	15.3	60	68.0	18.2	65

* n = 61

** n = 65

learning performance or AFQT scores. Those subjects ranking in the upper or lower third of the AFQT score continuum within their respective groups were assigned to subgroups to receive further analysis. Another set of subgroups was formed from those scoring in the upper or lower third of a score distribution on a learning performance trial within their respective group. The learning performance score was selected as the second trial for learning sentences in session four. This task of recalling complex material (sentences) with more than one presentation appeared to be representative of a classroom or instructional problem. In addition, the correlations of this trial with other learning tasks are

quite high suggesting that these scores are a reasonably stable measure of serial learning ability in both the experimental and control groups.

__Treatments__

Subjects were divided into an experimental group and a control group. Each member of the control group was instructed in conventional methods of serial learning: repetition, grouping, semantic linking, and word chaining. Repetition and semantic linking are described under the encoding strategies discussed previously in Experiment 1. Grouping is a technique in which the stimulus list is divided into small contiguous sets of three or four items. These item sets are then learned as if they were a unit. Chaining is a complex form of semantic linking. This technique involves the creation of a loose, verbal story to link the items of a list in serial order. The control group was taught all four of the verbal encoding methods during each instructional session with instructions to choose the method they felt was most helpful in learning and to use it as often as possible while learning the stimulus lists. The experimental group was taught only the imagery matrix encoding method using the same list of 30 alphanumerically cued image storage words used in Experiment 1. Both the experimental and the control groups were trained, practiced, and evaluated on learning performance tasks consisting of lists of words and lists of sentences.

__Training and Performance Testing__

Subjects were taught encoding methods and evaluated on learning performance in five 60-minute sessions, conducted on successive duty days. The first and third of these daily training sessions were devoted to the introduction and teaching of new encoding techniques. Sessions

two, four, and five were devoted to testing the subjects on the use of these techniques. Session two was used to evaluate the acquisition of words, session four the acquisition of sentences, and session five the acquisition of both words and sentences. Performance evaluation for sessions two and four was based on two trials of each list. All administration procedures for the second trial in each session were the same as for the first trial. Session five was an overall evaluation period for the acquisition of both words and sentences. For this last evaluation session the stimulus material consisted of a word list presented once and a sentence list presented twice. Both the experimental and control groups were divided into two subgroups; one subgroup of each group received the word list first, the other subgroup received the sentence list first. All training and testing were performed in a classroom setting administered by first-term airmen with little formal teaching experience.

Stimulus Lists

Stimulus lists consisted of words or sentences. The words used were concrete, highly imageable nouns which were given ratings by a group of airmen between 6 and 7 on a 7-point scale of concreteness similar to that used by Paivio, Yuille, and Maddigan (1968). The sentences were easily imaged, declarative, action statements of varied length and complexity (see Appendix D). Learning tasks were administered orally by an instructor in a standard classroom to groups of 35 to 40 basic trainees. There was approximately a 6-second pause between the presentation of each word and approximately a 12-second pause between the presentation of each sentence in the oral administration.

The stimulus lists were identical for the control and experimental groups. Training and practice lists for each group contained the same items, but the control subjects began practice with fewer stimulus items in the initial presentations and used several trials before attempting the full stimulus list.

Instructions to Subjects and Scoring

Subjects were instructed to reproduce the stimulus list in the correct numerical position on an answer sheet immediately following the presentation of the last item. If a subject was not sure of the correct serial position of a specific response, he was instructed to write it as near to the correct position as he could. Subjects were given as much time as necessary to complete the writing of their responses. Two types of scores were computed: a correct serial position score and an unordered recall score. Unless otherwise reported, all scores will be correct serial position scores. The scoring system used ignored spelling errors in scoring responses. A word item was marked correct if it was synonymous with the test item, i.e., trash can for garbage can. Sentences were scored as correct if they contained the same set of ideas as the test sentence. The development of this scoring system was influenced by the requirements of an instructional methodology as it might be applied in a classroom setting. This classroom orientation is reflected throughout the design of Experiment 2.

To explore the possibility that the encoding method used produced different amounts of detail in the response a quality of sentence recall score was developed and applied to the scoring of the sentences administered during the fifth session. A scoring key was developed by

identifying major themes in each sentence. Each response sentence was then scored on the number of major themes reproduced as compared with the total possible for that sentence. A sentence was considered to be attempted if at least one of the sentence themes was reproduced. Each subject received a total recall quality score by dividing the number of points he received by the number of points he would have gotten through perfect reproduction of each sentence attempted.

Results

Word List Performance

The mean number of words recalled in the correct serial position from the 30-word stimulus list presented in session two is shown in Table 30. The mean numbers of correctly positioned words on the first trial for the experimental and control group were 24.5 and 7.8, respectively. This difference is highly significant, F (1,124) = 384.54, $p < .01$. Both groups improved their scores on the second trial, producing means of 29.0 and 15.6, respectively. These differences between experimental and control group performance were also highly significant, F (1,124) = 187.0, $p < .01$.

Table 30

Mean Number of Words Recalled from a 30-Word Stimulus List, Correct Serial Position, Session Two, Two Trials
(N = 126)

Group		Trials: First	Trials: Second
Experimental			
	Mean	24.5*	29.0*
	σ	5.7	2.6
	n =	61	61
Control			
	Mean	7.8	15.6
	σ	3.7	7.3
	n =	65	65

* Difference between groups is significant at the .01 level.

The magnitude of the difference between the two groups noted on the first trial was not achieved on the second trial. The most probable

reason for the reduced difference is that the experimental group scores are limited to 30 correctly positioned words.

Analysis of the word list scores for the experimental and control groups displayed in Figures 11 and 12 for trials one and two compares the extent of differences in acquisition between the two groups. Most of the control subjects recalled 10 words or less on the first trial while very few of the experimental subjects produced scores this low. On the first trial with the stimulus word list, 14 out of 61 experimental subjects reproduced all 30 words; on the second trial the number of subjects recalling all 30 words increased to 47 out of 61.

Sentence List Performance

Training and practice in extending the application of encoding methods from the acquisition of word lists to the acquisition of more complex material, a list of 30 sentences, were conducted during the third experimental session for both encoding groups. The results of this training were evaluated 24 hours later, during session four, by administration of a new list of 30 sentences. Each sentence was repeated twice during each administration for the two trials. The recall data for the sentences are shown in Table 31. The difference between the mean recall scores for the experimental and control groups on the first trial was highly significant, $\underline{F}$ (1,124) = 93.66, $\underline{p} < .01$. The difference between the groups on the second trial was also highly significant, $\underline{F}$ (1,124) = 101.79, $\underline{p} < .01$.

Figures 13 and 14 show recall scores on trials one and two for the sentence list administered in session four. These graphically show that the magnitude of the performance difference is similar to that seen

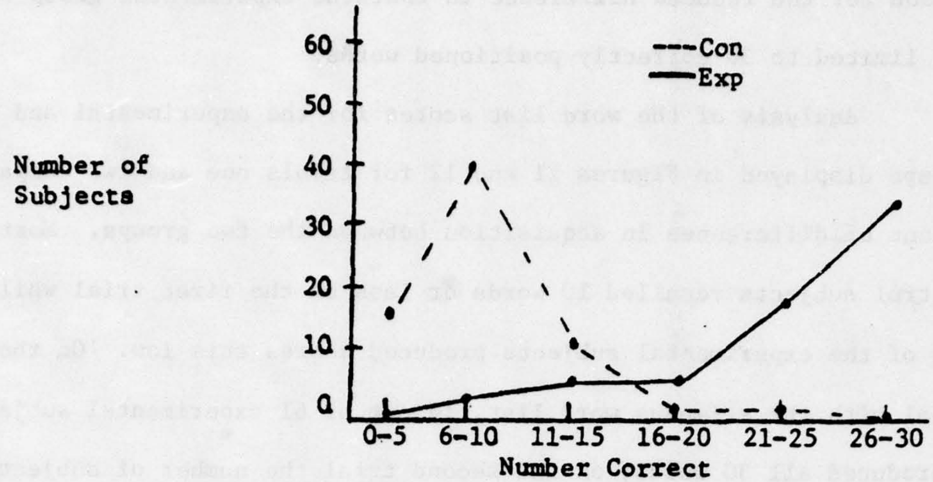

Figure 11. Distribution of Scores by Encoding Group on a List of 30 Words, First Trial , Session Two.

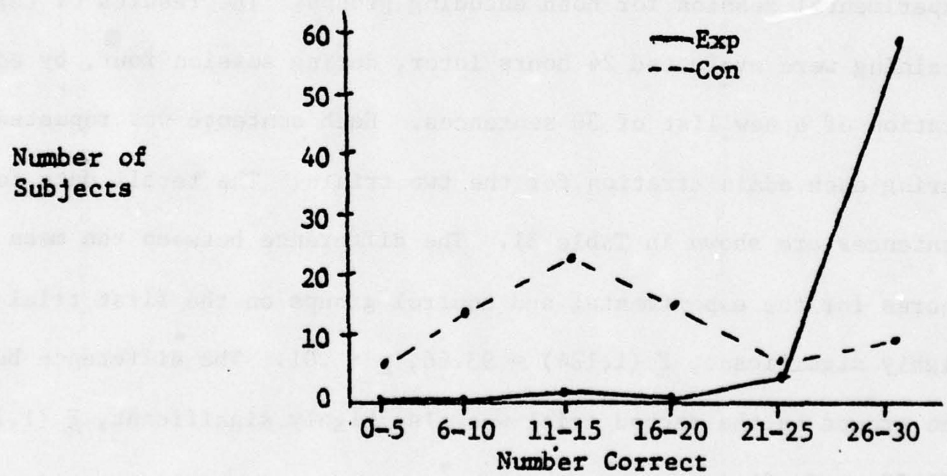

Figure 12. Distribution of Scores by Encoding Group on a List of 30 Words, Second Trial, Session Two.

in Figures 11 and 12 for the word list data. Sixty of the 66 control subjects recalled 10 sentences or less on the first trial; only 24 of the 61 experimental subjects scored at this level.

Table 31

Mean Number of Sentences Recalled from a 30-Sentence Stimulus List, Correct Serial Position, Session Four, Two Trials

Group		Trials: First	Trials: Second
Experimental			
	Mean	15.8*	23.0*
	σ	6.4	7.2
	_n_ =	61	61
Control			
	Mean	5.0	10.6
	σ	3.0	6.5
	_n_ =	65	65

* Difference between groups is significant at the .01 level.

Multilist Results

The fifth experimental session was designed to provide an overall evaluation of the acquisition rate of the experimental and control groups for encoding words and sentences. During this period new stimulus lists, one of 30 words repeated once and a list of 30 sentences repeated twice, were administered to both groups. To examine the effect of immediate reuse of the encoding techniques on encoding complex information the order of administration of the stimulus lists was reversed for one-half of the subjects in each encoding group. That is, the word list was administered first to one-half the subjects, the sentences were administered ahead of the word list to the other half.

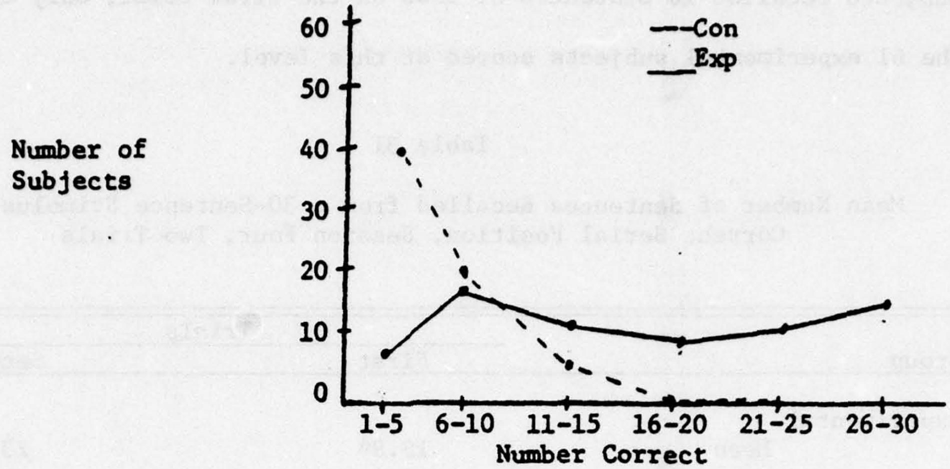

Figure 13. Distribution of Scores by Encoding Group on a List of 30 Sentences, First Trial, Session Four.

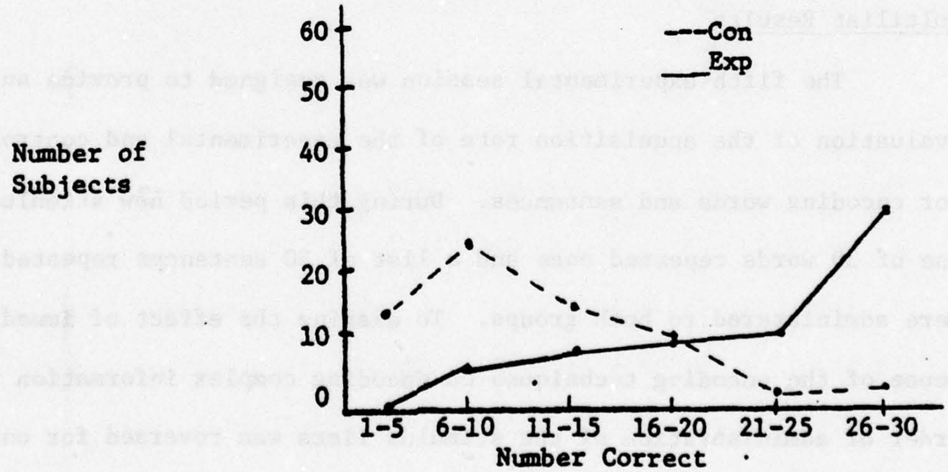

Figure 14. Distribution of Scores by Encoding Group on a List of 30 Sentences, Second Trial, Session Four.

Those subjects from each group who received the word list first followed by two presentations of the sentence list achieved acquisition scores on the word list similar to those they obtained during session two. The remaining half of both groups of subjects who received the sentence list presented twice followed by a single presentation of the word list achieved acquisition scores on both trials of the sentence list which approximated their performance on the sentence list administered during session four. These results, summarized in Table 32, show that there is little or no increase in recall scores from the second session to the fifth (words) and from the fourth session to the fifth (sentences). The similarities observed in the response data from two evaluation sessions suggest that practice effects may not be a significant factor in performance for either encoding group within this limited schedule of training.

Data on the effects of immediate reuse of an encoding technique are shown in Table 33. These data indicate that when a subject using the imagery matrix receives a second stimulus list closely following a prior list, the performance on the second list is reduced. The group of experimental subjects who received the word list first in session five have a significantly lower mean recall scores on both trials of the sentence list than for the sentence recall in session four, $\underline{F}$ (1, 26) = 46.95 and $\underline{F}$ (1, 26) = 18.32, $\underline{p}$ < .01 for the first and second trials respectively. Those experimental subjects who received the sentence list before receiving the word list in session five had reduced word list performance when compared to their word list recall scores in session two, $\underline{F}$ (1, 34) = 5.54, $\underline{p}$ < .05.

Table 32

Mean Number of Words Recalled in Sessions Two and Five and of Sentences Recalled in Sessions Four and Five with the Stimulus Presented First in Session Five

(N = 126)

		Learning Task					
		30 Words		30 Sentences			
		Session Two	Session Five	Session Four		Session Five	
Group		1st Trial	1st Trial	1st Trial	2nd Trial	1st Trial	2nd Trial
		(n = 27)		(n = 34)			
Experimental							
	Mean	24.7	25.0	14.6	22.1	15.0	23.3
	σ	5.9	6.4	7.8	7.4	8.0	7.8
		(n = 33)		(n = 32)			
Control							
	Mean	8.9	8.5	4.3	8.5	5.0	10.0*
	σ	4.2	4.2	2.7	5.0	2.7	5.5

*Mean performance gain of session five over session four is significant at the .05 level.

Unordered Recall Scores

To assess the extent to which subjects may recall items from the stimulus list and are unable to place them in the correct numeric position, two scores were computed for all learning trials. These scores were the correct serial position score which is a count of the recalled word in the correct serial position, and the unordered recall score which is the number of recalled responses without reference to serial position.

The unordered recall scores from sessions one and two displayed in Table 34 indicate that the experimental group achieved significantly

higher scores than the control group on the two trials of both the stimulus word list from session two, F (1, 124) = 235.06 and F (1, 124) = 140.47, $p < .01$, and the sentence list from session four, F (1, 124) = 74.02 and F (1, 124) = 80.22, $p < .01$.

Table 33

Mean Number of Words Recalled in Sessions Two and Four and of Sentences Recalled in Sessions Four and Five with the Stimulus List Presented Second in Session Five
(N = 126)

		Learning Task					
		30 Words		30 Sentences			
		Session Two	Session Five	Session Four		Session Five	
Group		1st Trial	1st Trial	1st Trial	2nd Trial	1st Trial	2nd Trial
		(n = 34)		(n = 27)			
Experimental							
	Mean	24.2	22.1*	17.4	24.3	9.8**	18.7**
	σ	5.6	6.3	9.1	7.0	6.6	8.7
		(n = 32)		(n = 33)			
Control							
	Mean	6.7	7.6	5.7	12.7	5.0	9.6
	σ	2.5	4.9	3.3	7.2	3.6	6.5

*Mean performance drop in session five from prior session is significant at .05.

**Mean performance drop in session five from prior session is significant at .01.

Primacy and Recency Effects

Learning curves based on the unordered recall scores for the word and sentence stimulus lists from session five are shown in Figures 15, 16, and 17 for the experimental and control groups. The curves were

Table 34

Means of Unordered Recall Scores for the Experimental and Control Groups for Sessions Two and Four (N = 126)

			Learning Task			
			Words		Sentences	
			1st	2nd	1st	2nd
Group		N	Trial	Trial	Trial	Trial
Experimental		61				
	Mean		24.7*	29.1*	16.5*	23.5*
	σ		5.5	2.6	8.3	6.8
Control		65				
	Mean		10.9	18.8	6.9	12.6
	σ		4.6	6.3	3.5	6.8

*Means of the experimental group scores are significantly greater than those for the control group at the .01 level.

computed using the average percentage of subjects recalling an item. These percentages are displayed in blocks of three items each. Inspection of the recall data in Figure 15 indicates a distinct difference in the form of the curves representing the two groups. The recall curve for the experimental group shows some primacy effect but little recency effect producing an almost flat acquisition curve for most of the items. The recall curves for the control group on the other hand show relatively strong primacy and recency effects, producing the U-shaped curve typically associated with serial learning tasks.

Learning curves generated from both trials of the more complex sentence material are shown in Figures 16 and 17 for the two groups. The curves for the sentence stimulus material display observable primacy and recency effects for both groups on each of the two trials.

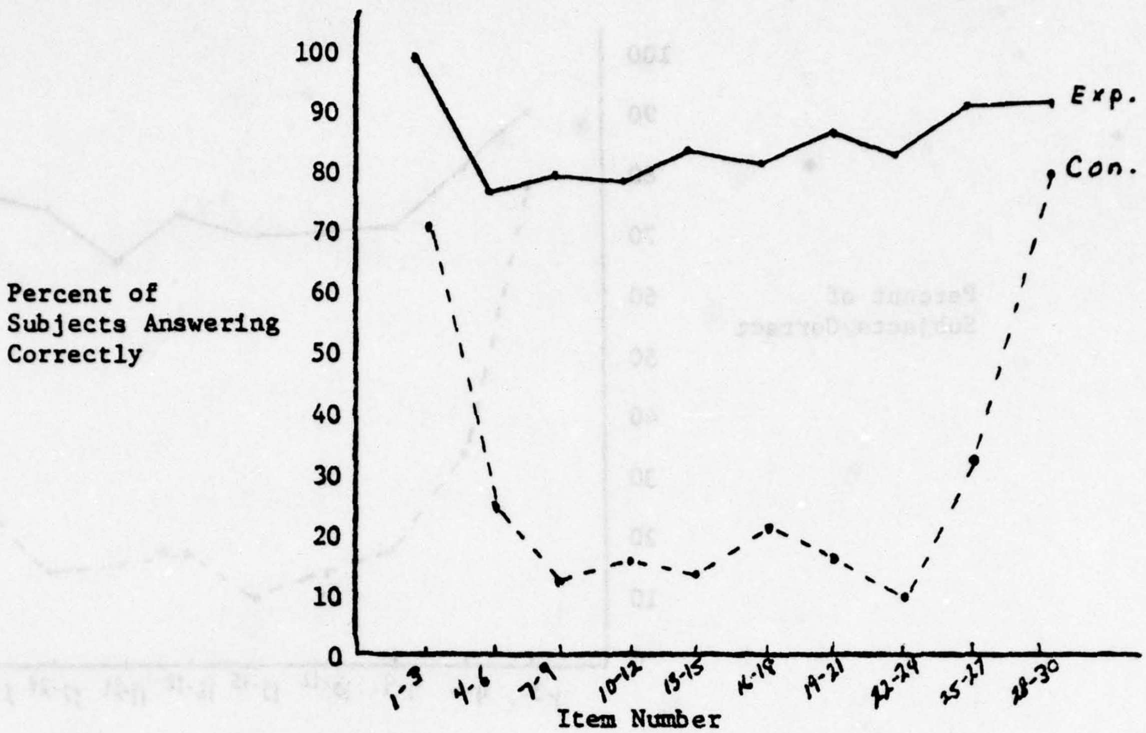

Figure 15. Percent of Subjects Answering Each Item Correctly Regardless of Numeric Order. (30 Word List, One Trial, Session Five)

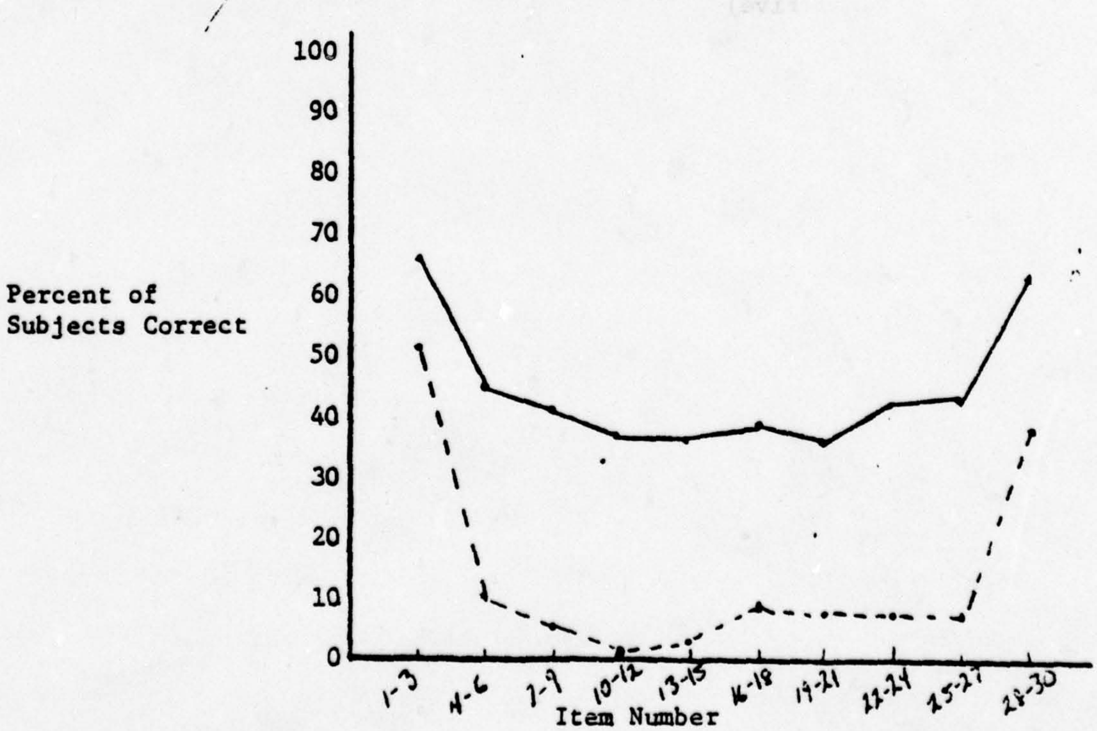

Figure 16. Percent of Subjects Answering Each Item Correctly Regardless of Numeric Order. (30 Sentence, First Trial, Session Five)

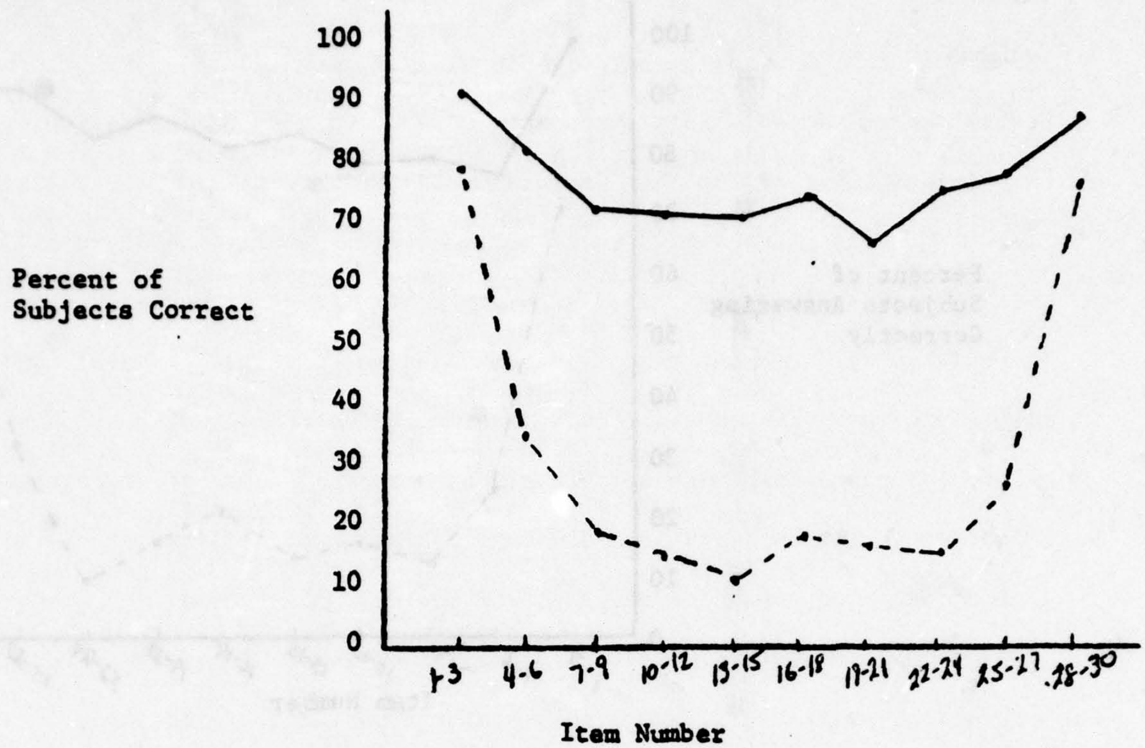

Figure 17. Percent of Subjects Answering Each Item Correctly Regardless of Numeric Order. (30 Sentence List, Second Trial, Session Five)

Quality of Reproduction

A measure of the quality of sentence reproduction was used to compare the information recalled for each sentence by the experimental and control groups. Scoring keys developed as described earlier under Instructions to Subjects and Scoring were used to score all responses to the stimulus sentences in session five. The data for the quality scores are displayed in Table 35. The experimental and control groups do not differ significantly on the quality of sentence reproduction for either the first or second trials. Both groups show improvement in their quality scores from trial one to trial two.

Table 35

Means of Quality Scores for Sentences Recalled in Session Five for the Experimental and Control Groups ($\underline{N}$ = 126)

		Quality Score Statistics	
Group	$\underline{N}$	First Trial	Second Trial
Experimental	61	87.2	90.3*
Control	65	84.6	88.4*

*Quality score on second trial is significantly greater than on first trial at .01 level.

Encoding Performance and Cognitive Ability

Assessing the relationship between learning rate, or performance on information acquisition, and measured aptitude is an important consideration in the evaluation of the potential utility of an element in an instructional methodology. Thus, the relationship between encoding ability or learning performance and measures of cognitive ability has

been of particular interest in this study. The performance data for both the experimental and control groups were correlated with the Armed Forces Qualification Test (AFQT) and the Mechanical, Administrative, General, and Electronics aptitude indices of the Armed Services Vocational Aptitude Battery (ASVAB-3). In addition, the encoding groups were divided into (1) high and low performance groups, and (2) high and low aptitude groups. The high and low performance groups were separately designated in order to examine more closely the specific attributes of verbal learning performance as achieved with different encoding methods and aptitude levels. The high and low aptitude subgroups were designed to provide a more detailed examination of learning performance differences within extreme aptitude levels. Since the correlational matrices are presented, these additional groupings of the data may seem redundant; however, in the evaluation of a novel encoding method there is a responsibility to determine if encoding performance differs in some unique way for those subgroups at the extremes of the performance or aptitude continuum which might not be observable in the context of the more general analysis.

Correlations between aptitude variables and performance on the learning tasks are provided in Table 36 for the control group and Table 37 for the experimental group. Table 36 shows moderate correlations between each of the learning performance scores with the AFQT and aptitude indices except for the Mechanical index and the fifth day sentence list with the Administrative index. Table 37 displays much the same pattern of correlations for the experimental group. Except for the session two word list and the session five word list, Table 37 indicates moderate correlations similar to those found for the control group. The

Table 36

Intercorrelations of the ASVAB Composites and Performance Measures of Recall for the Control Group
($\underline{N}$ = 65)

	1	2	3	4	5	6	7	8	9	10	11	12
1. AFQT												
2. Mech	.48**											
3. Admin	.42**	-.06										
4. General	.71**	.23	.43									
5. Elec	.88**	.59**	.31*	.50**								
Session Two Words												
6. 1st Trial	.34**	.06	.32*	.31*	.32*							
7. 2nd Trial	.40**	.06	.36**	.37**	.42**	.76**						
Session Four Sentences												
8. 1st Trial	.33**	.12	.25*	.18	.42**	.19	.48**					
9. 2nd Trial	.41**	.12	.47**	.21	.46**	.30*	.52**	.75**				
Session Five												
10. Words	.33**	.20	.08	.34**	.35**	.28*	.49**	.36**	.32*			
Sentences												
11. 1st Trial	.50**	.11	.21	.36**	.40**	.07	.33**	.49**	.50**	.36**		
12. 2nd Trial	.49**	.17	.32*	.43**	.12	.42**	.58**	.51**	.47**	.75**	.75**	

*.25 significant at the .05 level.
**.33 significant at the .01 level.

Table 37

Intercorrelations of the ASVAB Composites and Performance Measures of Recall for the Experimental Group ($\underline{N}$ = 61)

	1	2	3	4	5	6	7	8	9	10	11	12
1. AFQT												
2. Mech	.64**											
3. Admin	.48**	.25										
4. General	.81**	.38**	.54**									
5. Elec	.86**	.55**	.40**	.55**								
Session Two Words												
6. 1st Trial	.21	.08	.53**	.20	.23							
7. 2nd Trial	.03	.06	.19	.03	.01	.64**						
Session Four Sentences												
8. 1st Trial	.42**	.15	.42**	.23	.51**	.54**	.35**					
9. 2nd Trial	.34**	.16	.30*	.19	.39**	.46**	.44**	.85**				
Session Five												
10. Words	.19	.06	.47**	.15	.24	.62**	.54**	.54**	.48**			
Sentences												
11. 1st Trial	.30*	.16	.29*	.23	.39**	.47**	.31*	.68**	.60**	.39**		
12. 2nd Trial	.39**	.18	.32*	.35**	.40**	.48**	.42**	.61**	.62**	.40**	.86**	

*.26 significant at the .05 level.
**.33 significant at the .01 level.

large number of the experimental subjects obtaining near maximum scores on the word lists apparently attenuated the variance such that a significant correlation with the aptitude variables was not observed.

Performance and Ability

Subjects in both control and experimental groups were assigned to either high performance or low performance groups based upon their stimulus acquisition scores. The high performance subgroups were selected from the top third of the experimental and control groups and the low performance subgroups were selected from the lower third of their respective groups on the same measure. Performance scores for the recall of sentences on the second trial of session four were chosen as the criterion for determining the high and low performers.

The performance scores in Table 38 indicate experimental subjects with either high or low scores performed better on the average on the stimulus word list in session two than either group of performers among the control subjects. The low performers in the imagery matrix group have only slightly lower mean performance scores on the sentence list than the high performers in the control group.

Table 39 shows mean age, education, and aptitude scores for the high and low performers. The subgroups are not significantly different from each other on age or education. However, there are significant differences on some aptitude variables.

Aptitude and Performance Differences

Since verbal learning performance differences are reflected in different means on the AFQT and the Administrative and Electronic aptitude indexes, it is of interest to observe the extent of mean performance

Table 38

Mean Number of Words and Sentences Recalled for the High and Low Performance Groups of the Experimental and Control Groups ($\underline{N}$ = 87)

		Recall Task			
		30 Words		30 Sentences	
		Session Two		Session Four	
Group	$\underline{N}$	1st Trial	2nd Trial	1st Trial	2nd Trial
Experimental					
High Performance	21				
Mean		28.0**	30.0*	25.0**	29.9**
σ		2.3	0.0	3.8	0.3
Low Performance	20				
Mean		22.2	28.0	7.5	14.1
σ		6.0	4.0	4.0	4.8
Control					
High Performance	22				
Mean		8.7*	19.8**	7.7**	18.1**
σ		4.6	6.3	3.3	5.2
Low Performance	24				
Mean		6.3	11.3	2.8	4.9
σ		2.7	6.2	1.2	1.7

*Mean performance of high performers is significantly higher than low performers at .05 level.

**Mean performance of high performers is significantly higher than low performers at .01 level.

differences with the groups separated on the basis of aptitude scores. The control and experimental groups were separated into subgroups based on high and low AFQT scores. AFQT cutoff scores were selected separately for the experimental and control groups so as to include, as accurately as possible, one-third of each group in the high and low AFQT subgroups.

Table 39

Mean Age and Years of Education and Means of the ASVAB Composites of the High and Low Performance Groups in the Experimental and Control Groups
(N = 87)

Group	Age	Ed	AFQT	Mech	Admn	Genl	Elec
Experimental							
High							
Performance 21	19.3	12.2	69.2*	67.4	64.5*	71.2	76.0*
Low							
Performance 20	18.8	12.1	52.7	56.5	49.0	61.0	58.0
Control							
High							
Performance 22	19.8	12.3	69.5*	60.9	61.1*	69.3	75.7*
Low							
Performance 24	18.9	11.9	55.1	59.8	43.5	63.8	56.9

*Mean score of high performers is significantly different from low performers at the .01 level.

This selection procedure resulted in mean AFQT scores in the imagery matrix group of 78.7 for the high aptitude subgroup and 44.3 for the low subgroup. The mean scores for AFQT experimental and control group subjects in these subgroups were 80.9 and 45.0, respectively. Learning performance data on word and sentence lists administered in sessions two and four are displayed in Table 40.

The data in Table 40 show that the acquisition rate for the word and sentence lists was as high for the experimental subgroup, selected on low AFQT scores with a mean of 44, as that of the control subgroup, selected on high AFQT scores with a mean of 81.

Table 40

Means and Standard Deviations of the Mean Number of Words Recalled and Mean AFQT Scores for the High and Low AFQT Groups of the Experimental and Control Groups
(N = 89)

			Recall Task			
			30 Words		30 Sentences	
	Mean		Session Two		Session Four	
Group	AFQT	N	1st Trial	2nd Trial	1st Trial	2nd Trial
Experimental						
High						
Performance	79	21				
Mean			25.7	29.2	20.7**	26.1*
σ			5.5	1.7	8.2	6.5
Low						
Performance	44	21				
Mean			23.2	29.2	12.1	20.4
σ			5.1	1.3	7.0	7.1
Control						
High						
Performance	81	25				
Mean			9.6*	19.0*	6.0	13.6**
σ			3.6	7.7	2.9	6.8
Low						
Performance	45	22				
Mean			7.1	13.6	4.4	8.6
σ			3.8	6.9	3.0	5.0

*Mean performance on the recall task of high AFQT subjects is significantly greater than that of low AFQT subjects at .05 level.

**Mean performance on the recall task of high AFQT subjects is significantly greater than low AFQT scorers at .01 level.

For completeness in reporting, Table 41 shows mean age, education, and aptitude data for those in high and low AFQT scoring groups. These data simply show that creating high and low subgroups on one aptitude measure, the AFQT score results in splits for the samples scores on other correlated measures.

Table 41

Mean Age and Years of Education and Means of the ASVAB Composites of the Groups Based on High or Low Performance on the AFQT of Experimental and Control Groups

(N = 89)

Group	N	Age	Ed	AFQT	Mech	Admn	Genl	Elec
Experimental								
High AFQT	21	19.6	12.3	78.7*	73.3*	64.5*	81.7*	80.5*
Low AFQT	21	19.1	12.1	44.3	52.4	45.2	53.6	52.1
Control								
High AFQT	25	20.3	12.4	78.1*	70.2*	60.0*	81.8*	84.2*
Low AFQT	22	19.1	12.1	45.1	50.2	45.2	55.9	50.7

*Mean score of high AFQT group is significantly higher than mean scores of low AFQT group at the .01 level.

Discussion

Discussion of Hypotheses

The ninth hypothesis addresses the question of whether training in the use of the imagery matrix encoding technique can be conducted successfully in large classes. Basic to the evaluation of this question is (1) the generalizability of conditions under which subjects were taught and (2) the data on differences in recall between experimental and control groups.

Some factors that may influence generalizability of an instructional program to other classes are size of the group, student acquaintance with other group members, stability of group membership during the instructional period, and absenteeism and use of special equipment. Classes of subjects for encoding training were formed from basic training flights. These flights of approximately 40 members were assigned to encoding training classes on a chance basis. Original flight members, who comprised almost the total membership of the flights, had at least 7 days acquaintance with each other. The flight membership and therefore the class members remained very stable during the period of the experiment. Student absences from class were due to assignment to details, administrative processing, sick call, and other priority activities. The overall absentee rate was such that only about 75% of the trainees completed five consecutive training and testing periods. Returning absentees were treated as if they had not been absent. No effort was made to make up any missed instruction. However, they were not included in the data analysis. Training was conducted in standard classrooms with the only special equipment being a blackboard. The conditions of training described above do

not represent any unusual requirements and probably parallel training facilities and conditions readily available wherever classes are taught.

Before discussing the second question the following reservation should be made. Training in the use of all encoding methods required explanation and practice. In this classroom situation the experimental subjects have received a longer period of instruction in a specific technique than members of the control group. The control group received instruction and practice in four different verbal encoding methods during the same time the experimental group was being trained in the use of the imagery matrix method.

The data bearing on the question of the effectiveness of the training of the experimental group in the use of the imagery matrix is drawn from the recall performance data on the word list presented in session two, the sentences presented in session four, and a comparison of these data with benchmarks from Experiment 1. Examination of the recall data in Table 30 for the first trial indicates the mean number of words recalled are 24.5 and 7.8 for the experimental and control groups, respectively. The recall data in Table 31 for the first trial on a sentence list gives the mean number of sentences recalled as 15.8 and 5.0 for the experimental and control groups, respectively.

The magnitude of these differences is quite large as one set of means is three times the other and would seem to represent prima facie evidence that the training for the matrix method was quite satisfactory. The adequacy of the training cannot be judged on the basis of the size of the difference between encoding methods alone, rather the basic question is, is it as large or larger than would be obtained from training delivered under more carefully controlled, criterion referenced

conditions such as those in Experiment 1.

A direct statistical comparison between this data and that from Experiment 1 which was accomplished on a word list of the same length but different content is not feasible. The data may be used, however, to establish benchmarks for determining the expected range of differences in recall between other encoding techniques and the imagery matrix method. In Experiment 1 the training in each encoding method was highly structured, intensive, and conducted with individuals and small groups to a specific performance criterion. Thus data from this training regimen should provide a reasonable standard for estimating the effectiveness of the training given for encoding methods in other contexts if one accepts that encoding technique performance may generalize from one context, population, or word list to another. The data for the first two acquisition trials for all encoding groups in Experiment 1 on the initial learning task is used for this comparison and is displayed in Table 42.

Table 42

Mean Number of Words Recalled by Encoding Group, in Experiment 1 for Initial Learning Task, First and Second Trials

Trial No.	Repetition	Sem Link	Imag Chain	Imag Matrix
1	8.7	7.8	8.6	21.4
2	15.9	13.0	17.4	28.3

The data for the repetition and the imagery matrix groups from Experiment 1 shows a very close parallel with that in Table 30 for both

trials and encoding groups. The data in Table 30 with mean scores of 7.8 and 24.5 for the first trial and 15.6 and 29.0 for the second trial is extremely close to that shown in Table 42 for the repetition and imagery matrix encoding groups in Experiment 1. Despite some differences in word list content and method of presentation these data strongly suggest that training in the use of the imagery matrix encoding method was conducted as effectively in the classroom as in the closely controlled laboratory study. The demonstrated effectiveness of the imagery matrix encoding method in achieving higher acquisition rates across the differences in word list content, stimulus complexity, method of presentation, and population suggests the capacity for generalization to a rather broad range of instructional conditions.

The capability of the imagery matrix encoding method to process complex forms of information is crucial in determining its suitability as a component in an instructional system. The tenth hypothesis is concerned with the basic question of how well the imagery matrix encoding technique processes larger units of information such as sentences in comparison with the encoding methods of choice used by the control group.

This hypothesis is tested by a comparison between the experimental and control groups on recall performance for the lists of 30 sentences administered in sessions four and five. The data in Tables 31 and 32 are used to evaluate the extent to which the imagery matrix encoding method can process complex information. The difference between means for the two encoding groups are highly significant, $\underline{F}$ (1, 124) = 93.66, $\underline{p} < .01$ for the first trial, and $\underline{F}$ (1, 124) = 101.79, $\underline{p} < .01$ for the second trial. The magnitude of the differences in mean performance between the experimental and control groups for the two trials on the

sentence list, as displayed in Table 32 (session five), is comparable to that shown in Table 31. These data provide strong support for the hypothesis that the imagery matrix encoding method is relatively more effective for the processing of complex information than the encoding methods used by the control group. Whether this relative effectiveness is comparable to that attained by both encoding groups on the word list material can be estimated to some extent by examination of the ratios of performance on the first trial for both words and sentences for the experimental and control groups. These ratios of mean trials for sessions four and five are given in Table 43.

Table 43

Mean Number of Words or Sentences Recalled by the Experimental and the Control Group, and the Ratio of the Means of These Groups

	Word List Means	Ratio	Sentence List Means	Ratio
Experimental	24.5	3.14	15.8	3.16
Control	7.8		5.0	

The observed ratios are very similar suggesting information complexity applied a proportional burden across encoding methods. Thus the imagery matrix encoding technique appears to be relatively as effective with complex material as with smaller information units.

There is no evidence from these data that adding complexity to the stimulus units produces a new dimension in information processing requirements. It is possible that the sentences would require more time

to learn than words for both groups, but additional time would probably be proportional to task difficulty. The relationship of total time to total trials in measuring learning outcomes was investigated by Bugelski (1962) with the conclusion that trials and time could be considered as interchangeable units under most experimental conditions.

Discussion of Additional Results

The unordered recall scores for the control group in Table 34 show a gain of 3.2 words and 1.9 sentences over their correct serial position scores in Tables 29 and 30. These differences compare with a gain of unordered recall scores over the correct serial position scores of .1 words and .7 sentences for the experimental group. If the unordered recall scores for the control group were included in the analysis, some 27% would be added to their performance for the first trial of both words and sentences and 17% added on the second trial. The addition of the unordered recall scores from the first trial on word acquisition to the control group performance would reduce the difference in mean scores between the two groups from a ratio of 3.14 to 2.24. A reduction of this amount between the means would not change the statistical significance to an unacceptable level nor the judgments about the relative information processing capacity of the encoding methods. The unordered recall scores from the first trial on the word list for the control group are similar in their relation to correct serial position scores as those in Table 5 for the three non-matrix encoding groups on the recall task. The unordered recall scores for these groups in Table 5 average 3.9 words more than their correct serial position scores. These data suggest that use of the imagery matrix for encoding information

produces stronger positional associations during acquisition than other encoding methods. These results support, in part, the conclusion of Wood (1967) that the superiority of a mnemonic in information processing lies in the development of stronger positional associations. The theoretical implications of the stronger positional associations and the mechanisms which establish them during learning with the sequentially cued imagery matrix have not been the object of sufficient research to permit enlightened speculation.

The acquisition curves for the experimental and control groups on both the word and sentence lists are displayed graphically in Figures 15, 16, and 17 for assessment of the primacy and recency effects usually associated with serial learning. The acquisition curve for the control group on the first trial of the word list shown in Figure 15 has the deep "U" shape typical of primacy and recency effects in serial learning. The performance curve for the experimental group has a shallow "U" shape indicating a slight primacy effect and a negligible recency effect. The shape of these performance curves agree closely with the data from Experiment 1 in which the use of the imagery matrix encoding method produced only small primacy and recency effects in contrast with the other encoding methods. There is agreement also with the studies by Bugelski (1968, 1974) and Woods (1967) in which only slight primacy and recency effects were reported for imagery based and mnemonic encoding methods. Wood (1967) implied that the lack of primacy and recency effects when using the mnemonic method for serial learning occurs because serial learning in a paired associate paradigm does not produce serial position effects.

The serial position effects curves in Figure 16 for the first

trial of learning sentences, a more difficult task than learning words, show a pronounced "U" shape for both the experimental and control groups. When the performance curves in Figure 17, for the second trial, are compared with those in Figure 16 it appears that the curve retains about the same depth for the control groups, but it is much shallower for the experimental group. The acquisition curves in Figures 16 and 17 suggest a possible link between mastery level for the sentence list and the extent of the primacy and recency effects. The mastery level on the first trial in which the "U" shapes are most pronounced is a mean score of 5.0 for the control group and 15.8 for the experimental group. The higher mastery level for the second trial, a score of 23.0, for the experimental group is reflected in a straighter acquisition curve in Figure 17. There is little perceptible change in the shape or depth of the curve for the control group from Figure 16 to that seen in Figure 17; however, the mastery level of the control group is lower, with a score of 10.6 on the second trial than that for the experimental group on the first trial.

The presence of a clearly defined "U" shaped acquisition curve showing pronounced primacy and recency effects under conditions of incomplete mastery of the serial list when learning with the matrix method implies that both primacy and recency effects are produced in a wider range of circumstances than was previously thought. These data suggest that primacy and recency effects may be more strongly related to task difficulty level than to a specific serial learning model. Thus the lack of primacy and recency effects in other reported studies using the matrix method is more likely due to the mastery level of the list on the initial trial than to the use of a paired associate or serial

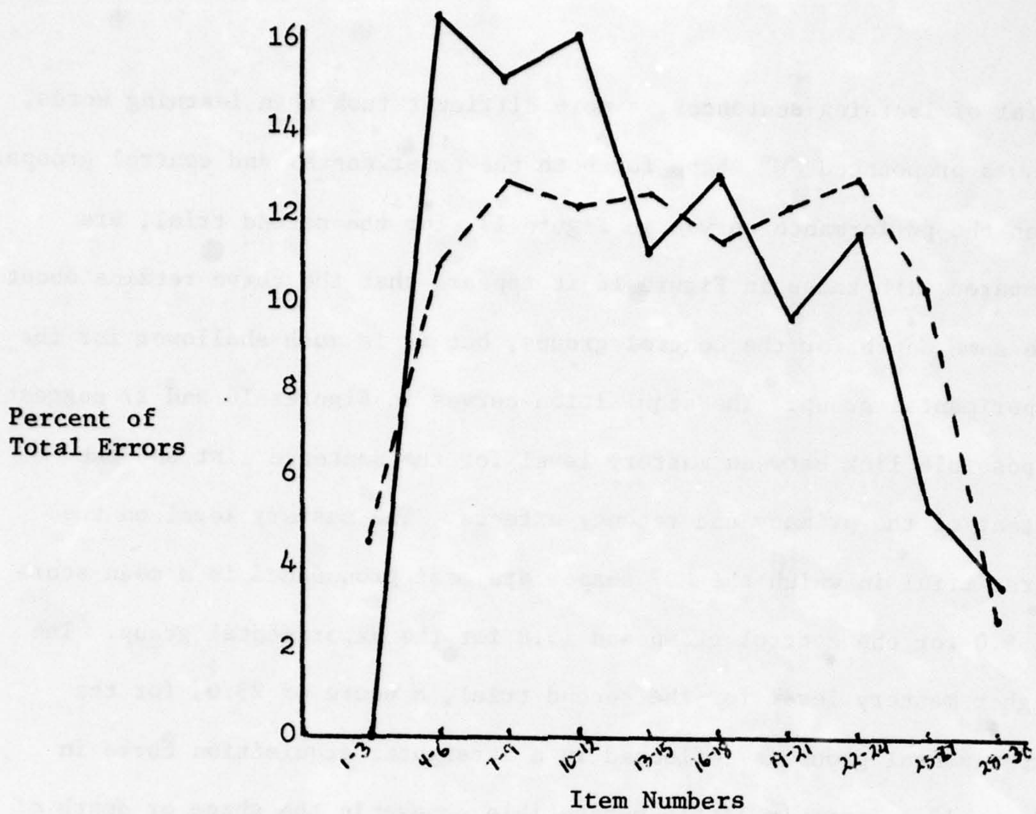

Figure 18. Percent of total errors for each block of items. (30 Word List, Session Five)

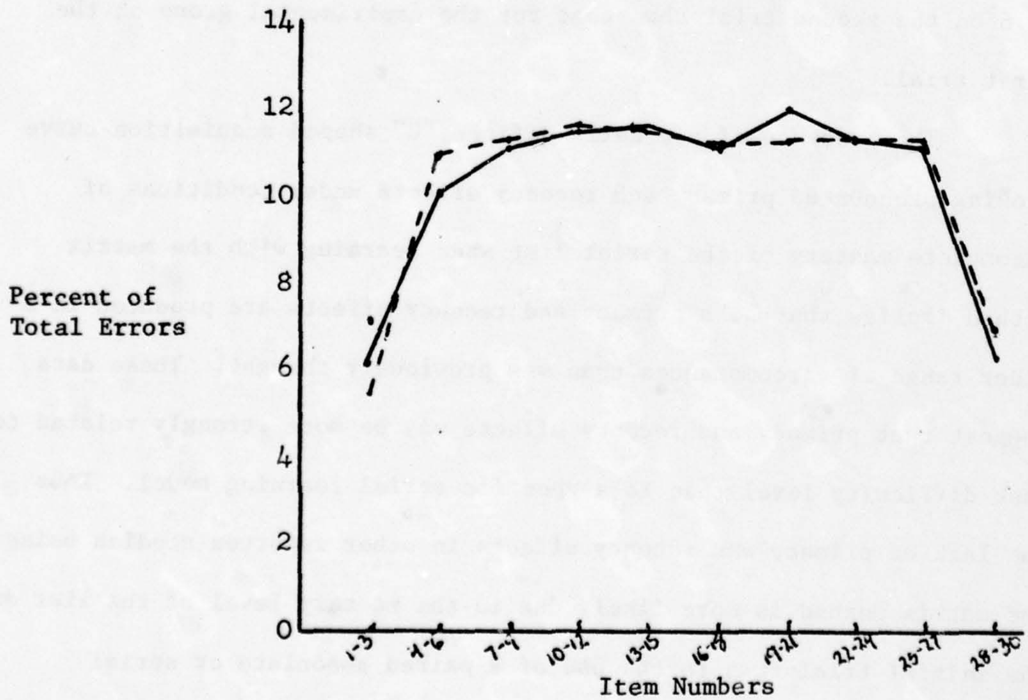

Figure 19. Percent of total errors for each block of items. (30 Sentences, Trial 1, Session Five)

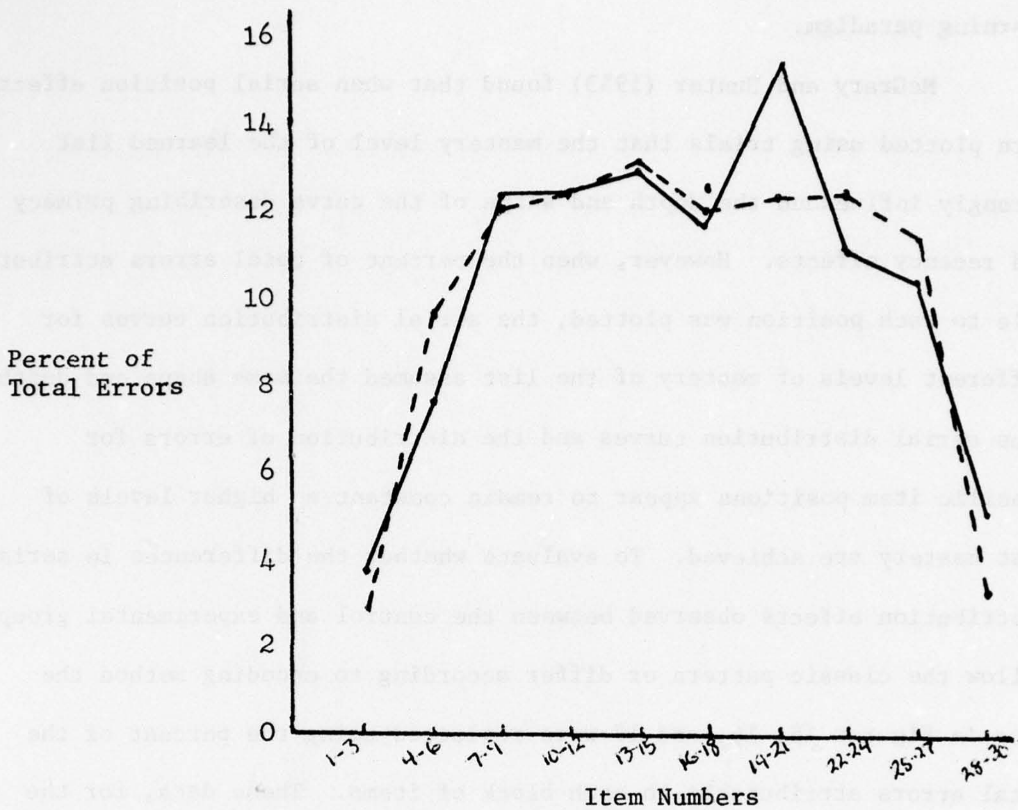

Figure 20. Percent of total errors for each block of items. (30 Sentences, Trial 2, Session Five)

learning paradigm.

McGrary and Hunter (1953) found that when serial position effects were plotted using trials that the mastery level of the learned list strongly influenced the depth and shape of the curve describing primacy and recency effects. However, when the percent of total errors attributable to each position was plotted, the serial distribution curves for different levels of mastery of the list assumed the same shape and depth. Thus serial distribution curves and the distribution of errors for specific item positions appear to remain constant as higher levels of list mastery are achieved. To evaluate whether the differences in serial distribution effects observed between the control and experimental groups follow the classic pattern or differ according to encoding method the data in Figures 15, 16, and 17 were replotted using the percent of the total errors attributable to each block of items. These data, for the serial position curves as replotted, are shown in Figures, 18, 19, and 20. These data show only small between group differences in both the shape and depth of the serial position curves indicating there are no differences in serial position distribution effects produced as a function of encoding method. It is apparent that the serial position effects resulting from the use of the matrix encoding methods are comparable to those produced by the control group.

The relationship of learning performance to measured aptitudes has been explored in both Experiments 1 and 2 to extend knowledge about the integration of ideational components and the use of different information encoding strategies. Such information may be particularly useful in suggesting lines of future research in identifying those aptitude areas which appear to contribute to learning performance for different

encoding techniques and for examining those components which may or may not influence encoding behavior at the extremes of the performance or aptitude distribution.

There is a pattern of significant correlations at the .01 level, in Tables 36 and 37, between performance on the learning of sentences and the AFQT, Administrative, General, and Electronics test scores common to both the experimental and control groups. There are isolated exceptions, such as the lack of a correlation significant at the .01 level between performances on sentences for the experimental group in session five and the administrative aptitude area. These exceptions are not so numerous as to negate the strength of the overall pattern of the relationship between learning performance and these aptitude measures.

The correlations between word lists and aptitude composites indicate a basic difference between the control and experimental groups in the pattern of these relationships. For the control group the first two learning trials on the word lists are significantly correlated with all aptitude scores except the mechanical aptitude composite. The experimental group has only one significant correlation with the aptitude scores for the first two learning trials. The control group also has more correlations between the word list and aptitude scores from session five than does the experimental group. The experimental group has a single correlation with an aptitude composite on this learning trial.

This lack of correlation between word list performance and aptitude for the imagery matrix group was observed in Experiment 1 and appears more related to the lack of variance in the performance data than to the use of some unique intellectual component in applying the imagery matrix encoding method. This observation is supported by the number of highly

significant correlations with other measures on the more complex task of learning sentences using the same encoding method. This observed relationship between performance and aptitude for both encoding groups has implications for hypothesis seven in Experiment 1. This hypothesis held that within group differences in learning rate would be related to aptitude; however, it was not supported by the word list data. It may be that this hypothesis is tenable only under conditions in which a challenging learning task is part of the experimental design. The data in both encoding groups for the learning of sentences appear to support the hypothesis.

The observed similarities in the aptitudes scores correlated to encoding performance for learning sentences suggest that both the experimental and control groups are drawing upon a common aptitude factorial structure during the encoding process. There is no evidence in these data of a unique, intellectual component in the use of an encoding strategy. This interpretation of the data suggests that the encoding of complex stimuli by any encoding method involves several aptitude areas.

Performance and AFQT Subgroups

The data in Table 38 indicate that the low performers in the experimental group have a superior learning rate on both trials of the word list compared to that of the high performers in the control group. This difference in acquisition rate disappears on the first trial in learning the sentence list, as the experimental group's low performers achieved scores of the same level as the control group's high performers. On the second trial, however, the control group's high performers had a

learning rate 28% higher than the experimental group's low performers. The reason for the reduction in rate of gain between the first and second trials for the experimental group's low performers is not clear. The differences in aptitude between the two groups, shown in Table 39, as estimated from the AFQT, Administrative, and Electronics scores may account for some of the observed reduction in learning rate when compared to the high performers in the control group. But these differences in aptitude scores do not seem sufficient to account for much of it, particularly when the performance of those with low AFQT scores using the matrix method as shown in Table 40 is considered.

The use of AFQT scores for assigning subjects to the upper or lower subgroups within their encoding group shows a wider spread between the experimental low AFQT subgroup and the control high AFQT subgroup than was apparent in the subgroups which were separated on encoding performance. The data in Table 40 show that the experimental low AFQT subgroup using the imagery matrix method had higher mean scores on both trials in learning word lists than the control high AFQT subgroup. The experimental groups were 242% higher on trial one and 154% higher on trial two. The experimental low AFQT subgroup's means for sentence acquisition were 100% higher on the first trial and 50% higher on the second trial than the means for the control high AFQT subgroup.

The data for the high and low AFQT experimental subgroups on the first and second trials of learning the words lists in Table 40 show no significant between group differences. The difference between the means for the first and second trials on learning the sentences are significant at the .01 and the .05 levels, respectively, for these two experimental subgroups. The control high and low AFQT subgroup means are significantly

different at the .05 level for both trials on the words lists and at the .01 level for the second trial on learning sentences. The difficulty level for learning the word list was apparently sufficient to produce performance differences within the control group. Differences within the experimental group, however, were noted only for acquisition of sentences which imposes a greater information processing load. These data may be interpreted as indicating that task difficulty may be determined as much by the encoding method used as by the complexity of the task.

Immediate Reuse of Encoding Technique

The learning of a different stimulus list immediately following the learning of an initial stimulus list was designed to evaluate the effects of immediate reuse of the encoding techniques on acquisition rate. The data from session five in Table 33 indicate there is no change in performance for the control subgroups stemming from the immediate reuse of their encoding strategies. However there is a significant drop in performance on the word list and on both trials of the sentence list for those subgroups using the imagery matrix encoding method. There is apparently a greater reduction in stimulus acquisition rate when the sentences (complex stimuli) are learned following acquisition of the word list (simple stimuli). The interference effect of learning the word list first on the immediate learning of sentences was apparently 35% for the first and 20% for the second trial when compared with the acquisition rates for learning the sentences first. The amount of interference effect shown here on learning the word list after learning the sentences first is approximately 12%.

The decrement in performance following immediate reuse of the

encoding technique for the matrix group may be due to an interference effect arising from an imagery based form of inhibition. The appearance of this interference may be associated with the persistence of the image from the earlier stimulus list stored in the imaginal matrix cells. This persistence was reported by several subjects. Possible causes for the persistence of the first image may be the initial development of unusually strong associations through a rehearsal and overlearning as that described by Underwood (1954) or the difficulty of the subject in constructing a new image not associated with the initial stimulus image. A third cause may be interference effects associated with an interaction of subject characteristics and encoding technique. It is possible, for example, that the stronger interference effects may occur among those with less ability to manipulate imagery. Exploration of this problem must await further research.

Summary of Experiment 2

The broad purpose of Experiment 2 is to evaluate the potential of the imagery matrix encoding method for application in an instructional technology. The immediate focus, however, is to determine the effectiveness of the matrix method when applied in a classroom environment and the extent to which the matrix method could be used to encode both simple stimuli (words) and complex stimuli (sentences).

The data indicate that the imagery matrix encoding method was sufficiently powerful to boost the acquisition rate for the experimental group to a level three times that of the control group. This difference in learning rate was maintained for the encoding of both simple and complex stimuli. The effectiveness of the experimental group's

performance in learning word lists was comparable to that obtained in Experiment 1 under carefully controlled conditions. Thus, the imagery matrix method appears to be a robust information encoding method suitable for either classroom or laboratory studies. The power of the imagery matrix method in accelerating acquisition over that of the control group is shown by the comparative performance of the high and low AFQT subgroups. The experimental low AFQT subgroup had a higher acquisition rate on both words and sentences than the control high AFQT subgroup. The quality of the replication of sentences was comparable for both groups and showed improvement with a second trial. The use of the imagery matrix method for learning a new stimulus list immediately after learning another stimulus list apparently arouses a form of interference which reduces acquisition rate from that normally achieved. However, the acquisition rate for use of the matrix method under conditions of interference remains substantially higher than that of the methods used by the control group. The use of the imagery matrix method does not appear to reduce the primacy and recency serial distribution curves associated with serial learning since the errors made during recall are apportioned among all item positions in the list in about the same pattern as for the control group.

Both the experimental and control group showed comparable patterns of significant correlations between learning performance on sentences and ASVAB aptitude composites. There was little comparability, however, in the pattern of relationships between aptitude and learning performance on word lists for the two groups.

Summary, Conclusions, and Applications

Summary

This report describes two experiments, one of which compares the information processing effectiveness of two verbally mediated and two imagery based encoding methods under rigorously controlled conditions. The second experiment compares the encoding effectiveness of a sequentially cued imagery matrix with that of the eclectic methods used by a control group practiced in the use of verbal encoding techniques in a classroom environment. The results obtained in Experiment 1 showed that use of the imagery matrix method provided superior performance on each of the four learning tasks; initial learning, recall, relearning, and interference learning. The imagery chaining method was more effective than the repetition encoding method in Experiment 1 on the initial and interference learning tasks. In Experiment 2 the experimental group using the matrix method outperformed the control group. A comparison of the acquisition rates for the repetition and imagery matrix groups between Experiments 1 and 2 indicates a similar level of differences for both the experimental and classroom conditions.

Encoding with the use of the imagery matrix provided stronger bonds between the stimulus and its designated position in the stimulus lists than other learning techniques. The positional bonds were stronger for the matrix group for word lists in Experiment 1 and for both words and sentences in Experiment 2. The use of imagery for the mediation of both simple and complex stimuli (sentences) indicates an advantage over the use of verbal encoding methods. This observed margin of superiority for the imagery matrix method in processing complex stimuli suggests

that imagery mediation may have a greater capacity for the acquisition, storage, and retrieval of information than has been discussed in the research literature.

The differences hypothesized between verbally mediated and imagery based methods for encoding concrete and abstract stimuli were not observed in this study. The data for the initial learning task in Experiment 1 is equivocal concerning whether verbal and imagery mediated encoding methods differ in encoding effectiveness for abstract and concrete stimuli. The indications from the data for the interference task, however, are that imagery based encoding is relatively more efficient with abstract material than verbally mediated methods. The data for the interference learning task further indicates that imagery mediation accommodates the acquisition of new material in an already learned stimulus list more effectively than verbally mediated methods.

Conclusions

These data provide convincing evidence that imagery based information encoding is superior to verbal mediation on the learning tasks posed in these studies. The results from this report which appear of significance for future research or development are:

(1) The use of constructed imagery is more effective for use in processing information than verbal mediation methods. The imagery chaining technique, which may be considered as the most basic method for the systematic manipulation of imagery for learning, produces a superior acquisition rate over the repetition encoding technique and is fully competitive with the acquisition rate obtained using the semantic linking technique. The sequentially cued imagery matrix is superior to all other

encoding methods compared in this study.

(2) The imagery based encoding method appears to be less sensitive to the influence of the abstract-concrete continuum on encoding than the verbal mediation methods.

(3) The imagery matrix method accepts new material into an already learned context with fewer trials and less interference with already learned material than other encoding methods.

(4) Imagery mediation is more effective in processing complex information than the verbal encoding methods.

(5) The techniques for the use of constructed imagery in information acquisition are easily learned and applied in a classroom environment.

(6) The use of imagery based encoding methods, as estimated from self reports, is less fatiguing than the use of verbal encoding methods.

The above findings provide vigorous support for the potential of the use of a sequentially cued imagery matrix encoding technique in an instructional technology.

The evaluation of a new learning strategy to improve individual information processing capacity in an instructional system raises a number of questions as to advantages over existing techniques. Basically these considerations refer to the following questions:

(1) How much real advantage in information acquisition rates over competing systems is provided?

(2) What is the information capacity or limit of the technique?

(3) How much information can be processed in a single unit or "chunk"?

(4) What types of information can be processed by this method?

(5) How much pretraining is necessary for students to function with the encoding method in class?

(6) How much preparation is required for instructional material to be presented by the recommended method?

The address of these questions is basic to any decisions to proceed further with the development of an instructional technique. The data in the two experiments described are derived from an array of learning tasks, stimulus qualities, and conditions, and are pertinent to these considerations.

The difference between the imagery matrix and the repetition encoding groups on mean acquisition rate in Experiment 1 is more than 2:1. The difference between the experimental and control groups in Experiment 2 in a classroom environment is 3:1. The magnitude of these differences is quite large by any standards, and the apparent potential for increasing the information acquisition rate in an instructional system is larger than for any other single training concept now under development. The evidence presented here shows that the imagery matrix has the potential for a high return on development efforts.

There is little evidence on which to base an estimate of the ultimate capacity of the imagery matrix for information acquisition, storage, and retrieval. Some evidence which may be applicable to this problem is reported by Haber (1970) and Wood (1967). Wood (1967) cited a study by Wallace, Turner, and Perkins (1957) in which subjects used imagery to bond 500 word pairs. The accuracy of recall of the response when given the stimulus words exceeded 95%. In another study they had subjects bond 700 word pairs and the accuracy of recalled responses

approached 90%. Haber (1970) explored the accuracy of recognition of visual images. He exposed a series of 2,500 pictures in two sessions of 4 hours each. He found that recognition accuracy under a variety of conditions and comparisons was in excess of 85%. Haber concluded from a series of studies that the storage capacity for visual imagery was almost limitless. These data provide a basis for inferring a large information storage capacity through the use of the imagery based encoding method.

The size or complexity of a unit or "chunk" of information which can be efficiently processed is an important element in learning rate and in the preparation of instructional material. Simon (1974), in a review, examined factors which determine the size of information chunks in the context of the span of apprehension. He found that information could be organized into larger wholes from almost any group or class of sub-elements, that the size of "chunks" in which information could be processed was related to the detailed knowledge and purpose of the individual handling the information. The data in Experiment 2 indicate that the imagery matrix group is as effective, relative to the control group, in encoding sentences as words. The upper limit to the number of elements of information which may be encoded into an image probably varies with the subject matter and the individual. The author has worked successfully with imagery training students who could encode paragraphs or pages as imagery units. These statements suggest an adequate encoding capacity for imagery units to meet most instructional needs.

The data for the encoding of abstract/concrete words suggests that imagery is as effective as verbal mediation for any type of

material. The method of Loci as described by Yates (1966) provides for storage of both words and objects. Atkinson (1975) describes an acoustic-imagery link which increased the learning rate for the foreign language equivalents of English words. Bugelski (1970) has performed studies which indicate that most ideas can be represented symbolically with sufficient reliability to be useful in information encoding.

The amount of pre-training required for students to use an encoding method depends upon the amount of information to be presented. The training for each step in the use of the imagery matrix technique required about 45 minutes (1st and 3rd days) in Experiment 2, but no additional training was required for the final learning session on the fifth day. The performance on this day was equivalent to that obtained on the second and fourth days, each of which followed a 45-minute period of instruction. Training is required, but the more often the matrix system is used, the less additional training will be required.

The amount of preparation required for subject matter content to be presented in a form suitable for encoding by the matrix method exceeds that required for making a very detailed class outline. However, the amount of detail would depend upon "chunk size" and other factors which need further study at this time.

Applications

The observed capacity of the imagery matrix method to encode information at a more rapid rate than competing learning methods, to accommodate to classroom conditions, to process both concrete and abstract material and to acquire and store large (sentence size) chunks of information in a single matrix position suggests that it has the potential as a powerful adjunct to instructional technology. The concept of mnemonic programming, an idea that the author has been developing around the imagery matrix concept for a number of years, now appears to be a realistic objective suitable for incorporation in an instructional system, and is suggested as the most promising follow-on research to further explore the capacity and the encoding characteristics of the imagery matrix method in information processing. The initial stages of the mnemonic programming system as conceived here require that both the instructor and student understand the imagery matrix methods and how to exercise it in simple learning tasks, i.e., learning work lists to some specific number of positions. The instructor then organizes the material to be presented in the form of a detailed outline. The subject matter is then further arrayed into imagery size chunks, with one chunk for each matrix position. The lesson material may be presented for acquisition either orally or in written form, with each imagery unit being clearly identified and its storage position specified. The instructor, during this process, assists the students in developing the imagery symbols or forms necessary for storage when the object, nomenclature or ideas are unfamiliar in a usual sense - the amount of the assistance depending upon the facility of the students with the matrix system and the subject matter under study. There are a number of options as to methods for reviewing the stored information for clarity and precision, evaluating the amount of material stored and reenforcing the positional associations for each imagery unit during a class period.

The simplistic instructional paradigm described above has been pretested with a number of subjects using both connected

discourse (written) and related learning tasks (orally presented). The results to date indicate that a high level of mastery is produced for the simple kinds of subject matter used so far.

There are a number of methodological problems which require addressing to provide useful measurement and analysis of the large amount of information which can be encoded in only a few hours of class time.

Some rather unsystematic attempts have been made to evaluate the potential use of material learned in this manner for deep processing, e.g.,can material stored in this way be readily and meaningfully related to other ideas, concepts or information. The preliminary indications are quite positive that information acquired through use of the imagery matrix is not sealed off or separated from the logical, associative or judgemental processes.

There remains a number of procedural problems to be overcome, however, there have been few negative indicators that imaginal encoding and the imagery matrix concept in particular will not provide a powerful adjunct to instructional technology and a new basis for the study of ideational processes and ideational functioning.

The problem area of learning enhancement, as described by Engelbart (1962, 1965) has not been discussed in reference to the large differences in the information processing rates observed in both Experiments 1 and 2. Criteria which appear useful for defining learning enhancement are quite complex and have not yet been described with sufficient clarity to provide the experimental basis for an initial assessment of this idea. However, the results of this study suggest that an encoding method is now available which may be useful for exploring a learning enhancement concept. It is now feasible to discuss the design parameters and methodology for learning enhancement experiments in which greater quantities of data and more varied stimuli may be used to study the learning process from a new perspective.

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APPENDIX A

1. Subject Agreement
2. Data Forms
3. Guidelines for conduct of the study and Encoding Directions

Date______________________________

CONSENT OF PARTICIPANT

I, ______________________________________, agree to particpate in a serial learning study conducted by F. R. Ratliff. I understand that:

1. The purpose of this study is to evaluate different methods of learning, not to evaluate my individual ability to learn.

2. I am expected to actively and conscientiously participate in four sessions: the first for orientation and preliminary testing, the second for training in my assigned learning method, and the last two sessions for applying my assigned method.

3. I will be paid $2.50 per hour for my participating only after attending all four scheduled sessions.

4. I may withdraw from the study at any time, but I would then forfeit my claim to compensation.

5. All personal information will be treated as confidential and will be used only when grouped with data from other participants.

______________________________ ______________________________

Witnessed Participant's Signature

SERIAL LEARNING STUDY

Here is your schedule for the remaining sessions:

Session	Date	Time	Place
2			
3			
4			

If you have any questions, call F. R. Ratliff at 653-1689 or 671-2957.

Do not write in
this space

ID____________
GROUP__________
LIST___________

PARTICIPANT INFORMATION SHEET

NAME____
Last First Middle

MAILING ADDRESS____

TELEPHONE

SEX: M F CLASS: FR SOPH JR SR GR AGE

MAJOR:

____Humanities (English, Foreign Languages, Music, Philosophy, Religion, etc.)
____Social Sciences (Anthropology, Economics, Government, Psychology, etc.)
____Biological Sciences (Biology, Medicine, Nutrition, Zoology, etc.)
____Physical Sciences (Chemistry, Computer Science, Mathematics, Physics, etc.)
____Other (please specify) ______________________________________
____Number of children in family
____Your birth order (i.e., "1" means "first born")
Father's occupation __________________________________
Your major language __________________________________
The major language in your home: ________________________

Do not write below the double line

	Date	In	Out	Elapsed	Comp
1					
2					
3					
4					

SS ______
TR 1 ______
TR 2 ______
EXP ______

CTMM

A	B	C	D	E	F	G
H	I	J	K	L	M	N

INFORMATION FOR THE PARTICIPANT

The purpose of this study is to evaluate the effectiveness of different learning methods, not your individual ability to learn. We want to determine whether the practiced and disciplined use of a specific learning method will lead to more rapid learning and more accurate recall.

You will attend four sessions, which we will arrange to fit your schedule as well as possible. The first session is for orientation and preliminary testing. At this time you will be scheduled for the remaining three sessions. There may be up to two weeks between the orientation session and the first of the remaining three sessions.

You will be paid $2.50 per hour for your participation. It is crucial to the study that each participant attend and actively participate in all four sessions. Because of this you will receive your money only after completing the fourth session. You may withdraw from the study at any time, though you would then forfeit your claim to compensation.

You will be assigned a specific learning method. You will be trained in its use during the second session. In the third and fourth sessions you will be given the opportunity to use your method and to see how well it works for you.

Because we are testing not you, but the method, it is essential that you use only the learning method assigned to you and that you use it continuously throughout each learning session.

All personal information will be treated as confidential and will be used only when grouped with data from other participants.

GUIDELINES FOR THE CONDUCT OF LEARNING METHODS STUDY

At each session E will greet S and provide proper seating. E will then state the purpose of the meeting and proceed according to the instructions for that session.

During sessions II thru IV, S will be provided with a copy of the Information for Participants, the Learning Method, answer sheets, and pencils. During the practice and learning trials, answer sheets will be collected after each trial.

The S's questions about meeting schedules or applying the assigned learning method will be answered. However, no information about other learning methods or the specific content of future meetings will be provided, e.g., next time you will relearn this list, etc.

E SHOULD KEEP IN MIND AT ALL TIMES THAT THE PURPOSE OF THIS STUDY IS TO PROVIDE A TEST OF DIFFERENCES BETWEEN RIGOROUSLY PRACTICED AND APPLIED LEARNING METHODS. Thus he should make every reasonable effort to insure that S is applying the assigned method. This effort may include questions to S between list displays. Normally, two Es will be present at each session if four or more Ss are present.

SESSION I (Orientation and testing)

E greets and seats S and provides copies of (1) Information to Participants form, and (2) a Participant Consent form, and says, "You are here to participate in a study to evaluate the effectiveness of different learning methods for learning and recalling information. This session is devoted to orientation, preliminary testing, and the scheduling of the next three sessions. Please read the information on both forms, and if you agree to the terms as expressed, sign the consent agreement. If you have any questions I will discuss them with you.

"It is critical to the study that you fully understand that you must use the learning method you are assigned. When you sign the consent form, you are agreeing to a vigorous, dedicated performance of the assigned learning technique."

E administers the short form of the California Test of Mental Maturity (level 5) and the Speed of Spelling Test. Later, S is assigned to an information encoding group and is scheduled for a training session and two testing sessions.

Scheduling of small groups of S (4 to 8) using the same encoding technique for the same session is desirable.

SESSION II (Training and practice)

E seats S and provides copies of (1) the Information to the Participant Form, (2) a description of the Learning Method to which S has been assigned, (3) answer sheets, and (4) pencils. E then says, "This session is for training you in the assigned learning method and to provide practice in using it until you demonstrate proficiency with it.

"The learning method assigned to you is. . . . This method is described in detail on your sheet labeled LEARNING METHOD: . . . . I will summarize the procedures to be followed in applying this method, then you may read it in detail. You may ask questions about the method until you feel that you clearly understand what is to be done. You may be familiar with other learning methods; if so, please do not discuss them or plan to use them here."

E summarizes the method to be used, then allows S approximately three minutes to read the instructions, then asks, "Are there any questions?"

When the questions are answered and the discussion completed, E again summarizes the procedure required to use the learning method. E then says, "You will now practice, using the assigned learning method, under the same conditions you will have during the later sessions. Your task is to learn a list of 30 words in the correct numerical order in the least number of trials. Each word with its sequence number will be shown for six seconds. As each word is shown you will apply the learning method. When the first trial with the list is completed after number 30, begin writing those words you can recall in the numbered spaces on the answer sheet. Try to write each word in its proper place, i.e., next to its corresponding number. However, if you cannot do this, write every word you can recall even if you are not sure where it belongs. If there are questions about how to apply the method, we will stop and discuss it. Practice will continue until you can use the technique well."

After each repetition of the word list, S will fill out the answer sheet as he would in the testing trials. E will begin each trial with the statement: "Get ready for the first word in trial ____." After each repetition of the list, S will be allowed three minutes, or until he draws a blank, for writing recall responses. Collect the answer sheets after each trial. Following the practice session, S is scheduled for the remaining two learning sessions.

NOTE THESE TWO SESSIONS MUST BE SCHEDULED APPROXIMATELY 24 HOURS APART.

SESSION III (Testing 1)

E seats S and confirms the following day's appointment. He then provides the information sheet, learning method instructions, answer sheets, and pencils. E then guides S in a review of the learning method for a maximum of five minutes. E then says, "Your task is to learn a list of 30 words in the correct numerical order in the least number of trials. Each word with its sequence number will be shown for six seconds.

As each word is shown, you will apply the assigned learning method. When the first trial with the list is completed (word number 30), begin writing those words you can recall in the numbered space on the answer sheet. Write every word you can recall even if you are not sure where it belongs. Keep writing until you draw a blank."

E then says, "Get ready for the first word in crial one."

The projector is set on automatic, and when number 30 has been shown, E says, "The first trial is complete, begin writing those words you can recall in the numbered spaces on the answer sheet. Try to write each word in its proper place. If you cannot do this, write every word you can recall even if you are not sure where it belongs."

At the end of three minutes, or when S has stopped writing, E collects the answer sheet and says, "Get ready for the first word in trial two" and the list is repeated. Each succeeding trial is conducted in the same manner.

When S has made one errorless repetition of the list or has completed ten trials, the appointment for the following day is confirmed and S is released.

SESSION IV (Testing 2)

E seats S, provides copies of the information form, the learning methods description, answer sheets, and pencils. The basics of the learning method are reviewed for a maximum of two minutes. E then says, "During the last session you were given a list of thirty wwords to learn. Today I want you to recall as many of those words as you can. Remember to put them with their corresponding number when possible."

When three minutes have elapsed, or S has stopped writing, take the answer sheet and say, "Now your task is to relearn the word list you learned at the last session. The learning method and procedures are the same as before. Relearn the list with the least number of trials. You will be allowed ten trials."

The relearning trials are started by the same procedure used in session III. When the criterion is reached, E says, "You will be shown another list that contains some new words and some words from the old list. You will receive ten trials to learn this list using the same procedure as before. Try to learn it in the fewest number of trials possible."

Follow the procedure described in session three until the criterion is reached. The S is administered the post-test questionnaire, thanked for his participation, and is paid for the time he has spent on the study.

LEARNING METHOD: REPETITION

You have been assigned the repetition method for learning in this

study. All of your learning in this study will be done using the repetition method.

Repeating information until it is learned and can be recalled is one of the more common methods of learning and is very effective when effort and attention are properly used. Repetition of words in small groups, or "chains," develops associations between the words which lead to learning and recall. The number of words you use in a group or chain is a matter of personal taste and judgement. During the training and practice session you should determine the number of words to repeat in a chain that is right for you.

Repetition may be performed aloud or to yourself as long as you mentally "hear" the words you are repeating. Attend closely to each word you repeat to avoid losing the associations within your chain.

The repetition procedure is outlined below:

1. Begin repeating the first word as soon as it is shown on the screen. e.g., horse, horse, horse, . . .

2. When the second word is displayed, repeat it two or three times. Then repeat the first and second words together, e.g., horse, fence, horse, fence, . . .

3. When the third word is displayed repeat it two or three times, then repeat it in a chain with the other, e.g., horse, fence, tree, horse, fence, . . .

4. Continue adding words to your chain until you feel that it is getting too long to handle. Then begin dropping words from the first of the chain, e.g., fence, tree, chair, fence, tree, chair,. . .

Do not hestiate to change the length of your chain or the speed of your repetition if it helps your performance. Keep your attention focused on the words you are repeating.

Your task is to learn a list of 30 words in the correct numerical order in the least number of trials. Each word with its sequence number will be shown for six seconds. As each new word is shown, apply the repetition method. When the first trial with the word list is completed (after word 30), begin writing those words you can recall in the numbered spaces on the answer sheet. Try to write each word in its proper place, i.e., next to its corresponding number. However, if you cannot do this, write every word you can recall even if you are not sure where it belongs.

During practice feel free to ask questions until you understand this method completely. You may refer to this sheet at any time during the sessions.

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A COMPARISON OF VERBAL AND VISUAL IMAGERY LEARNING STRATEGIES: --ETC(U)
DEC 78 F R RATLIFF, J A EARLES, J D RATLIFF AFOSR-76-2973

UNCLASSIFIED AFOSR-TR-79-0673 NL

3 OF 3

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LEARNING METHOD: VERBAL LINKING

You have been assigned the verbal linking method for learning in this study. All of your learning in this study will be done using the verbal linking method.

The use of verbs or adjectives to link words in a list to be learned is very effective when properly used. Placing an action or descriptive term between words will strengthen the associations between them. For example, placing a word like "rub" between horse and tree develops a stronger recall bond between them. With a list of five words to learn, such as horse, tree, fence, chair, and grass, the addition of linking words between them improves recall. Notice the improved bonding between these words when verbs or adjectives are used to link them: horse (rubs) tree (shades) fence (surrounds) chair (stands) grass.

In learning a long list of words, it is important to repeat groups of verbally linked words. The effect of adding the linking words is to reduce the number of repetitions necessary for learning the list. The length of the word group, or "chain," you repeat is a matter of personal taste and judgment. During the training and practice session, you should determine the number of words that you can easily link into a chain.

Repetition and linking of words and word groups may be performed aloud or to yourself as long as you mentally "hear" the words you are repeating. Attend closely to each word from the list and to each linking word to avoid losing your chain or associations.

The verbal linking procedure is outlined below:

1. Begin repeating the first word as soon as it is shown on the screen, e.g., horse, horse, horse, ...

2. When the second word is displayed, repeat it two or three times. Then think of an action or descriptive word that can link the first two words. Use this term to form a bond between the first two words as you repeat them. Repeat these first two words with their linking word until the next word is shown, e.g., horse (rubs) tree . . . horse (rubs) tree . . . horse (rubs) tree . . . .

3. When the third word is displayed, repeat it two or three times. Then think of another descriptive term to link the second and third words, e.g., horse (rubs) tree (shades) fence . . . horse (rubs) tree (shades) fence . . . horse (rubs) tree (shades) fence . . . .

4. Continue adding words to your chain until you feel that it is getting too long to handle. Then begin dropping words from the front of the chain, e.g., tree (shades) fence (surrounds) chair . . . (shades) fence (surrounds) chair . . . tree (shades) fence (surrounds) chair . . . .

Do not hesitate to change the length of your chain or the speed of your repetition if it helps your performance. Keep your attention focused on the words (and their links) that you are repeating.

Your task is to learn a list of 30 words in the correct numerical order in the least number of trials. Each word with its sequence number will be shown for six seconds. As each new word is shown, apply the verbal linking method. When the first trial with the word list is completed (after word 30), begin writing those words you can recall in the numbered spaces on the answer sheet. Try to write each word in its proper place, i.e., next to its corresponding number. However, if you cannot do this write every word you can recall even if you are not sure where it belongs.

During practice feel free to ask questions until you understand this method completely. You may refer to this sheet at any time during the sessions.

LEARNING METHOD: IMAGERY CHAINING

You have been assigned the imagery chaining method of learning in this study. All of your learning in this study will be done using the imagery chaining method.

Mental images that are intentionally formed of a word, object, or event are easily recalled. Imagery chaining is the process of forming a mental image of each word to be learned and then linking these together to form a "chain" of images. Two images can be linked or "chained" into a long series by partially overlapping them. This chain of images can be recalled by mentally scanning from one image to another.

The imagery chaining procedure is outlined below:

1. Form an image of the first word when it is shown, e.g., form a mental image of a <u>horse</u>.

2. When the second word is shown, form an image of it, e.g., form an image of a <u>tree</u>.

3. Now move, in your mind, this image until it overlaps part of your first image, e.g., move the image of the <u>tree</u> until it overlaps part of the <u>horse</u>.

4. When the third word is shown, form an image of it, e.g., form an image of a <u>fence</u>.

5. Now move this image until it overlaps part of the second image, e.g., move the <u>fence</u> until it overlaps part of the <u>tree</u>. Continue doing this with the rest of the list.

Images developed and linked together in this way are easily recalled. Recall of the first image leads to visualization of the second image and so on throughout the entire list.

Here are some guidelines to help you use the imagery chaining method:

- Make the images bright and vivid.

- Make the images about the same size. The image of an elephant and a wrist watch must be comparable in size so they can be seen as "chained" together.

- Overlap the images so that the next image in line is clearly and easily seen when mentally "looking" at the first image.

- Generate an interaction between the images when linking them, e.g., image the horse rubbing the tree and the tree shading the fence.

- Use the time a word is displayed to form an image of the word and to link it to the image of the last word displayed. If there is time before the next word is shown, review the last one or two images you have chained.

Keep your attention focused on the words being shown and on the images you are forming and linking.

Your task is to learn a list of 30 words in the correct numerical order in the least number of trials. Each word with its sequence number will be shown for six seconds. As each new word is shown, apply the imagery chaining method. When the first trial with the word list is completed (after word 30), begin writing those words you can recall in the numbered spaces on the answer sheet. Try to write each word in its proper place, i.e., next to its corresponding number. However, if you cannot do this, write every word you can recall even if you are not sure where it belongs.

During practice feel free to ask questions until you understand this method completely. You may refer to this sheet at any time during the sessions.

LEARNING METHOD: PEGWORD IMAGERY

You have been assigned the pegword imagery method for learning. All of your learning in this study will be done using the pegword imagery method.

Mental images that you intentionally form of a word, idea, or object are easily recalled. As you form images, their size and shape can be controlled to suit your needs. Learning by pegword imagery is done by the conscious development of a series of images that can be used as mental storage boxes for other information or ideas.

The pegwords (see the pegword list) you form into storage images are based on a number-letter code which places each pegword by a certain

number. Thus, the number of each pegword and its place in the list is always known.

Learning with pegword imagery requires making an image of each of the 30 pegwords. An image of a pegword is easily formed if you accept an image that comes clearly to mind as you look at or think about the pegword. The image formed in this way should be bright, vivid, and stable. For example, in forming images of the first five pegwords (1. Tea, 2. Noah, 3. May, 4. Ray, and 5. Law), note that the first word tea evokes an image. This image may be a cup of hot tea, a glass of iced tea, a tea bag or whatever tea means to you personally. You can determine the image that best fits your meaning of tea. Each of the other pegwords will evoke imagery. Form imagery for each pegword that best represents its meaning to you and has an area where stored words or objects are plainly visible.

With five pegword images formed, you are ready to use them as storage boxes for other words. Assume you are to remember the words horse, tree, fence, chair, and grass. The first step is to form an image of a horse, then move this image inside your image of tea (a cup of tea?). You control the size and shape of the imagined horse so that it fits in the cup of tea. When you look at the pegword image later, you will see the image of the horse inside it.

Repeat this process with tree (form an image of a tree and place it in Noah's hands). Form images for fence, chair, and grass and place them in the proper pegword image. Now look in each pegword image and observe the objects (images) you have stored there. You should see the horse in the pegword image of tea, the tree in the pegword image of Noah, etc., for each pegword.

Form clear, vivid images for the remaining pegwords. Work at each image until it is stable and has an area where stored information is easily recognized.

The pegword imagery learning method is outlined below:

1. Develop a clear, vivid image of each of the 30 pegwords. Select an area in each pegword image where you can easily see stored words to be recalled.

2. Form an image of the word to be recalled and move it into the focal area of the pegword image.

3. As you move a word image into the pegword, try to develop some interaction between the two images, i.e., the horse moving in the tea cup, Noah handling the tree, etc.

4. When a word is displayed, form an image of it and move it to a visible area of the pegword image. If there is time before the next word is displayed, look at the next pegword to become more familiar with its image.

Your task is to learn a list of 30 words in the correct numerical order in the least number of trials. Each word with its sequence number will be shown for six seconds. As each new word is shown, apply the peg-word imagery system. When the first trial with the word list is completed (after word 30), begin writing those you can recall in the numbered spaces on the answer sheet. Try to write each word in its proper place, i.e., next to its corresponding number. However, if you cannot do this, write every word you can recall even if you are not sure where it belongs.

During practice, feel free to ask questions until you understand this method completely. You may refer to these directions at any time during the sessions.

MNEMONIC PEGWORD LIST

1.	tea	6.	jaw	11.	tot	16.	tissue	21.	net	26.	niche
2.	Noah	7.	key	12.	tan	17.	tack	22.	noon	27.	neck
3.	May	8.	fee	13.	tam	18.	taffy	23.	Nome	28.	navy
4.	ray	9.	bay	14.	tar	19.	tap	24.	Nero	29.	nap
5.	law	10.	toes	15.	tail	20.	noose	25.	nail	30.	mass

NUMBER CODE

1.	t	5.	l	9.	p, b
2.	n	6.	sh, ch, j	10.	z, s
3.	m	7.	k, hard c		
4.	r	8.	f, v		

APPENDIX C

1. List of Variables

2. Method for Scoring Subjects Response Protocols

3. Analysis Plan

4. List of Scores Generated for the Total Population and for Each Group

5. The Measurement of Orderliness in Serial Learning, Ratliff, J.D.

VARIABLES LIST

N OF CASES 130
VAR LABELS
VAR01,ID/
02,GROUP/
03,AGE/
04,GENDER/
05,EDUCATIONAL LEVEL/
06,MAJOR/
07,NUMBER OF CHILDREN IN FAMILY/
08,BIRTH ORDER/
09,FATHERS OCCUPATION/
10,CTMM LOGICAL REASONING/
11,CTMM NUMERICAL REASONING/
12,CTMM VERBAL CONCEPTS/
13,CTMM MEMORY/
14,CTMM LANGUAGE/
15,CTMM NON-LANGUAGE/
16,CTMM TOTAL/
17,SPEED OF SPELLING TRIAL 1/
18,SPEED OF SPELLING TRIAL 2/
19,SPEED OF SPELLING EXPERIMENTAL/
20,ELAPSED TIME SESSION 1/
21,ELAPSED TIME SESSION 2/
22,ELAPSED TIME SESSION 3/
23,ELAPSED TIME SESSION 4/
24,PRACTICE, TOTAL TRIALS/
25,PRACTICE, TOTAL WORD CORRECT, IN ORDER/
26,PRACTICE,TOTAL WORDS CORRECT, FREE RECALL/
27,LEARN,TOTAL TRIALS/
28,LEARN,TOTAL WORDS CORRECT, IN ORDER/
29,LEARN,TOTAL WORDS CORRECT, FREE RECALL/
30,RECALL,TOTAL WORDS CORRECT, IN ORDER/
31,RECALL,TOTAL WORDS CORRECT, FREE RECALL/
32,RELEARN,TOTAL TRIALS/
33,RELEARN,TOTAL WORDS CORRECT, IN ORDER/
34,RELEARN, TOTAL WORDS CORRECT, FREE RECALL/
35,NEWLEARN,TOTAL TRAILS/
36,NEWLEARN,TOTAL WORDS CORRECT, IN ORDER/
37,NEWLEARN,TOTAL WORDS CORRECT, FREE RECALL/
VAR38,POST TREATMENT QUESTIONNAIRE 1/
39,POST TREATMENT QUESTIONNAIRE 2/
40,POST TREATMENT QUESTIONNAIRE 3/
41,POST TREATMENT QUESTIONNAIRE 4/
42,POST TREATMENT QUESTIONNAIRE 5/
43,POST TREATMENT QUESTIONNAIRE 6/
44,POST TREATMENT QUESTIONNAIRE 7/
45,POST TREATMENT QUESTIONNAIRE 8/
46,POST TREATMENT QUESTIONNAIRE 9/
47,POST TREATMENT QUESTIONNAIRE 10/
48,GORDON VISUAL IMAGERY 1/
49,GORDON VISUAL IMAGERY 2/
50,GORDON VISUAL IMAGERY 3/
51,GORDON VISUAL IMAGERY 4/
52,GORDON VISUAL IMAGERY 5/
53,GORDON VISUAL IMAGERY 6/
54,GORDON VISUAL IMAGERY 7/
55,GORDON VISUAL IMAGERY 8/
56,GORDON VISUAL IMAGERY 9/
57,GORDON VISUAL IMAGERY 10/
58,GORDON VISUAL IMAGERY 11/
59,GORDON VISUAL IMAGERY 12/
60,IMAGERY,VISION/
61,IMAGERY,AUDITORY/
62,IMAGERY,TACTILE/
63,IMAGERY,TASTE/
64,IMAGERY,KINESTHETIC/
65,IMAGERY,OLFACTION/
66,LEARN,TOTAL ABSTRACT WORDS/
67,LEARN,TOTAL CONCRETE WORDS/
68,RECALL,TOTAL ABSTRACT WORDS/
69,RECALL,TOTAL CONCRETE WORDS/
VALUE LABELS
VAR02,
(1)REPETITION
(2)VERBAL LINKING
(3)IMAGERY CHAINING
(4)PEG WORDS
(5)VERBAL LINKING,REVERSED LIST/
VAR04,
(1)MALE
(2)FEMALE
VAR05,
(0)HIGH SCHOOL
(1)FRESHMAN
(2)SOPHOMORE
(3)JUNIOR
(4)SENIOR
(5)GRADUATE/

VAR06,
(0)NONE OR UNDECIDED
(1)HUMANITIES
(2)SOCIAL SCIENCES
(3)BIOLOGICAL SCIENCES
(4)PHYSICAL SCIENCES
(5)OTHER/
VAR09,
(0)DECEASED
(1)PROFESSIONAL
(2)MANAGERIAL,FOREMAN
(3)FARMERS
(4)CLERICAL
(5)SALES
(6)CRAFTSMAN
(7)OPERATIVES
(8)SERVICE,SOME TRAINING
(9)SERVICE,LITTLE-NO TRAINING
(10)UNSKILLED
(11)HOUSEWIFE
(12)NOT IN LABOR FORCE/
VAR38 TO VAR47
(1)A
(2)B
(3)C
(4)D
(5)E/
VAR48 TO VAR59
(1)YES
(2)NO
(3)UNSURE/

METHOD FOR SCORING SUBJECTS' RESPONSE PROTOCOLS

Each subject's response protocols for each trial were scored as follows:

1) UNORDERED RECALL SCORE = The number of items on the protocol which also appear on the stimulus list (duplicate responses are not counted).

2) RELATIVE SERIAL POSITION SCORE = The number of items on the protocol list which are in the same serial position as on the stimulus list, and divided by the number of items (unordered recall score) on the protocol list.

3) ABSOLUTE SERIAL POSITION SCORE = The number of items on the protocol list which are in the same serial position as on the stimulus list divided by 30.

4) ABSOLUTE ORDERLINESS = Number of elements in order on protocol list divided by 435.

5) RELATIVE ORDERLINESS = The number of elements in order on protocol list divided by $\frac{n\,(n-1)}{2}$, where n is the number of items on the protocol list.

6) UNORDERED RECALL SCORE/ABSTRACT WORDS = The number of abstract items on the protocol which also appear on the stimulus list.

7) ABSOLUTE SERIAL POSITION SCORE/ABSTRACT WORDS = The number of abstract items on the protocol, which are in the same serial position as on the stimulus list divided by 15.

8) SERIAL POSITION SCORE/ABSTRACT WORDS = The number of abstract items on the protocol which are in the same serial position as on the stimulus list divided by the score in item 6 (unordered recall score).

9) UNORDERED RECALL SCORE/CONCRETE WORDS = The number of concrete words (items) on the protocol which also appear on the stimulus list.

10) RELATIVE SERIAL POSITION SCORE/CONCRETE WORDS = The number of concrete items on the protocol which also appear on the stimulus list, divided by the score on item 9.

11) ABSOLUTE SERIAL POSITION SCORE/CONCRETE WORDS = The number of concrete items on the protocol which are in the same serial position as on the stimulus list, divided by 15.

Each item is scored as to (1) trial of first recall and (2) trial of first correct placement.

SCORES GENERATED FOR THE POPULATION AND EACH GROUP

POPULATION LEARNING CURVES - ORIGINAL LEARN	S 0001
GROUP I LEARNING CURVES - ORIGINAL LEARN	S 0002
GROUP II LEARNING CURVES - ORIGINAL LEARN	S 0003
GROUP III LEARNING CURVES - ORIGINAL LEARN	S 0004
GROUP IV LEARNING CURVES - ORIGINAL LEARN	S 0005
POPULATION LEARNING CURVES - RECALL + RELEARN	S 0006
GROUP I LEARNING CURVES - RECALL + RELEARN	S 0007
GROUP II LEARNING CURVES - RECALL + RELEARN	S 0008
GROUP III LEARNING CURVES - RECALL + RELEARN	S 0009
GROUP IV LEARNING CURVES - RECALL + RELEARN	S 0010
POPULATION LEARNING CURVES - NEW LEARN	S 0011
GROUP I LEARNING CURVES - NEW LEARN	S 0012
GROUP II LEARNING CURVES - NEW LEARN	S 0013
GROUP III LEARNING CURVES - NEW LEARN	S 0014
GROUP IV LEARNING CURVES - NEW LEARN	S 0015
UNORDERED RECALL LEARNING CURVES ORIGINAL LEARN	S 0016
ABSOLUTE SERIAL POSITION LEARNING CURVES ORIGINAL LEARN	S 0017
RELATIVE SERIAL POSITION LEARNING CURVES ORIGINAL LEARN	S 0018
ABSOLUTE ORDERLINESS LEARNING CURVES ORIGINAL LEARN	S 0019
RELATIVE ORDERLINESS LEARNING CURVES ORIGINAL LEARN	S 0020
UNORDERED RECALL LEARNING CURVES RECALL + RELEARN	S 0021
ABSOLUTE SERIAL POSITION LEARNING CURVES RECALL + RELEARN	S 0022
RELATIVE SERIAL POSITION LEARNING CURVES RECALL + RELEARN	S 0023
ABSOLUTE ORDERLINESS LEARNING CURVES RECALL + RELEARN	S 0024
RELATIVE ORDERLINESS LEARNING CURVES RECALL + RELEARN	S 0025
UNORDERED RECALL LEARNING CURVES NEW LEARN	S 0026
ABSOLUTE SERIAL POSITION LEARNING CURVES NEW LEARN	S 0027
RELATIVE SERIAL POSITION LEARNING CURVES NEW LEARN	S 0028
ABSOLUTE ORDERLINESS LEARNING CURVES NEW LEARN	S 0029
RELATIVE ORDERLINESS LEARNING CURVES NEW LEARN	S 0030
ABSTRACT/UNORDERED RECALL LEARNING CURVES - ORIGINAL LEARN	S 0031
ABSTRACT/ABSOLUTE SERIAL POSITION LEARNING CURVES - ORIGINAL LEARN	S 0032
ABSTRACT/RELATIVE SERIAL POSITION LEARNING CURVES - ORIGINAL LEARN	S 0033
CONCRETE/UNORDERED RECALL LEARNING CURVES - ORIGINAL LEARN	S 0034
CONCRETE/ABSOLUTE SERIAL POSITION LEARNING CURVES - ORIGINAL LEARN	S 0035
CONCRETE/RELATIVE SERIAL POSITION LEARNING CURVES - ORIGINAL LEARN	S 0036
ABSTRACT/UNORDERED RECALL LEARNING CURVES - RECALL + RELEARN	S 0037
ABSTRACT/ABSOLUTE SERIAL POSITION LEARNING CURVES - RECALL + RELEARN	S 0038
ABSTRACT/RELATIVE SERIAL POSITION LEARNING CURVES - RECALL + RELEARN	S 0039
CONCRETE/UNORDERED RECALL LEARNING CURVES - RECALL + RELEARN	S 0040
CONCRETE/ABSOLUTE SERIAL POSITION LEARNING CURVES - RECALL + RELEARN	S 0041
CONCRETE/RELATIVE SERIAL POSITION LEARNING CURVES - RECALL + RELEARN	S 0042

CON/UNORDERED RECALL	POPULATION	NEW LEARN	0191
CON/UNORDERED RECALL	SAMPLE=GROUP I	NEW LEARN	0192
CON/UNORDERED RECALL	SAMPLE=GROUP II	NEW LEARN	0193
CON/UNORDERED RECALL	SAMPLE=GROUP III	NEW LEARN	0194
CON/UNORDERED RECALL	SAMPLE=GROUP IV	NEW LEARN	0195
CON/ABSOLUTE SERIAL POS.	POPULATION	NEW LEARN	0196
CON/ABSOLUTE SERIAL POS.	SAMPLE=GROUP I	NEW LEARN	0197
CON/ABSOLUTE SERIAL POS.	SAMPLE=GROUP II	NEW LEARN	0198
CON/ABSOLUTE SERIAL POS.	SAMPLE=GROUP III	NEW LEARN	0199
CON/ABSOLUTE SERIAL POS.	SAMPLE=GROUP IV	NEW LEARN	0200
CON/RELATIVE SERIAL POS.	POPULATION	NEW LEARN	0201
CON/RELATIVE SERIAL POS.	SAMPLE=GROUP I	NEW LEARN	0202
CON/RELATIVE SERIAL POS.	SAMPLE=GROUP II	NEW LEARN	0203
CON/RELATIVE SERIAL POS.	SAMPLE=GROUP III	NEW LEARN	0204
CON/RELATIVE SERIAL POS.	SAMPLE=GROUP IV	NEW LEARN	0205

The Measurement of Orderliness in Serial Learning

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ABSTRACT

Much information about the order of items in a stimulus list may exist in a recalled list without being reflected by a serial position score. A technique is presented for measuring the otherwise latent orderliness between two lists by analyzing the occurrence of items relative to each other, rather than relative to their serial positions. The score so generated permits the analysis of the fine structure of the recall in order to study the details of the learning process. A flowchart algorithm well suited for computer adaptation is included.

In the study of serial learning, a score based only on the serial positions of recalled items cannot tell the complete story of how much learning has taken place. To illustrate this let us consider the following five-item stimulus list and two recalled lists:

stimulus list: A B C D E
recalled list 1: A B C D E
recalled list 2: E A B C D.

If we now analyze the learning of the stimulus list in terms of correct serial position replication, we get the following evaluation: List 1 has been learned completely (every item is reproduced in its correct serial position), and list 2 has not been learned at all (i.e., not a single item appears in the same location on both the stimulus and recalled lists.)

But a quick glance at the second list shows that this appraisal based purely on the serial position of each item is not at all a fair one. The sequence A B C D, a most significant feature of the stimulus list, appears completely intact in the second recalled list. Obviously list 2 represents the learning of much information about the stimulus list, although none of this learning is revealed by studying the serial positions of the recalled items. Where much learning has occurred, serial position evaluative methods indicate that none has.

So we must find another perspective from which to analyze if we are to *more fully explore serial* learning. The significance of the A B C D sequence of list 2 is not in the relation each item of the sequence bears to its serial position in the list, for indeed each is incorrectly so related; rather, the significance of the sequence exists in the relation each item bears to the other items in the sequence. What is important is that A falls before B, C, and D; that B falls before C and D; and that C falls before D. If we are to detect and measure the kind of information which went undetected in list 2 when we used only analysis of serial position, we must use a technique which will recognize sequences of properly ordered items irrespective of their serial positions in a list.

To develop such a technique we must change our emphasis away from proper placement of items on the number line of the list; we must emphasize, instead, the proper <u>orderliness</u> of the items. The distinction is clear. The first orientation relates each item to its place in a fixed frame of reference, the list itself. The new orientation relates each item to each and every other item in all their diverse locations.

The definition of orderliness to be presented depends upon the elements of order. Two items constitute an element of order if the items occur in the same sequence in both the stimulus list and the recalled list, regardless of other items which may occur between them.

For illustration let us look at the following four-item stimulus and recalled lists:

stimulus list: A B C D
recalled list: D B A C.

In this recalled list there are two elements of order, the item pairs AC and BC; in both lists A and B precede C. There are no elements of order containing D, because D precedes all other items in the recalled list but follows all other items in the stimulus list.

To further exemplify the definition of the element of order let us examine one more recalled list using the same stimulus list as above:

recalled list: A C D B.

It should be clear that this list contains four elements of order: AC, AD, AB, and CD.

We now define the orderliness of a recalled list as the number of elements of order in the list, divided by the $n(n-1)/2$ elements of order which would be present if the list were perfectly ordered. This division normalizes the score, so that all scores fall in the range zero to one.

An orderliness score of one indicates that the recalled list is an exact replica of the stimulus list. A score of zero indicates that the recalled list is the mirror image of the stimulus list.

Figure 1 presents in flowchart form an algorithm which is the mathematical embodiment of this definition of list orderliness.

The first decision box asks the question: does the j-th item of the recalled list occur anywhere among the first $k-1$ items of the stimulus list? If so, then the item pair $R(j), R(i)$ is an element of order. The variable <u>COUNT</u>, which tallies the number of elements of order as they are found by the algorithm, is increased by one.

In the last box, after the list has been thoroughly searched for signs of orderliness, <u>COUNT</u> is divided by $n(n-1)/2$, thus yielding the desired measure of orderliness.

Table 1 contains orderliness scores computed for each permutation of a four-item list.

In practical research not all items of the stimulus list will always be recalled, or some items may appear on a recalled list which were not on the stimulus list. In these situations a similar measure of orderliness may also be usefully computed. By dividing the number of elements in a recalled list by $m(m-1)/2$, where m is the number of items which appear on both the stimulus and recalled lists, we would have a measure of the relative orderliness of the items recalled, irrespective of how many items remain unlearned.

These two measures of orderliness, when used in conjunction with measures of unordered recall and proper serial position placement, provide

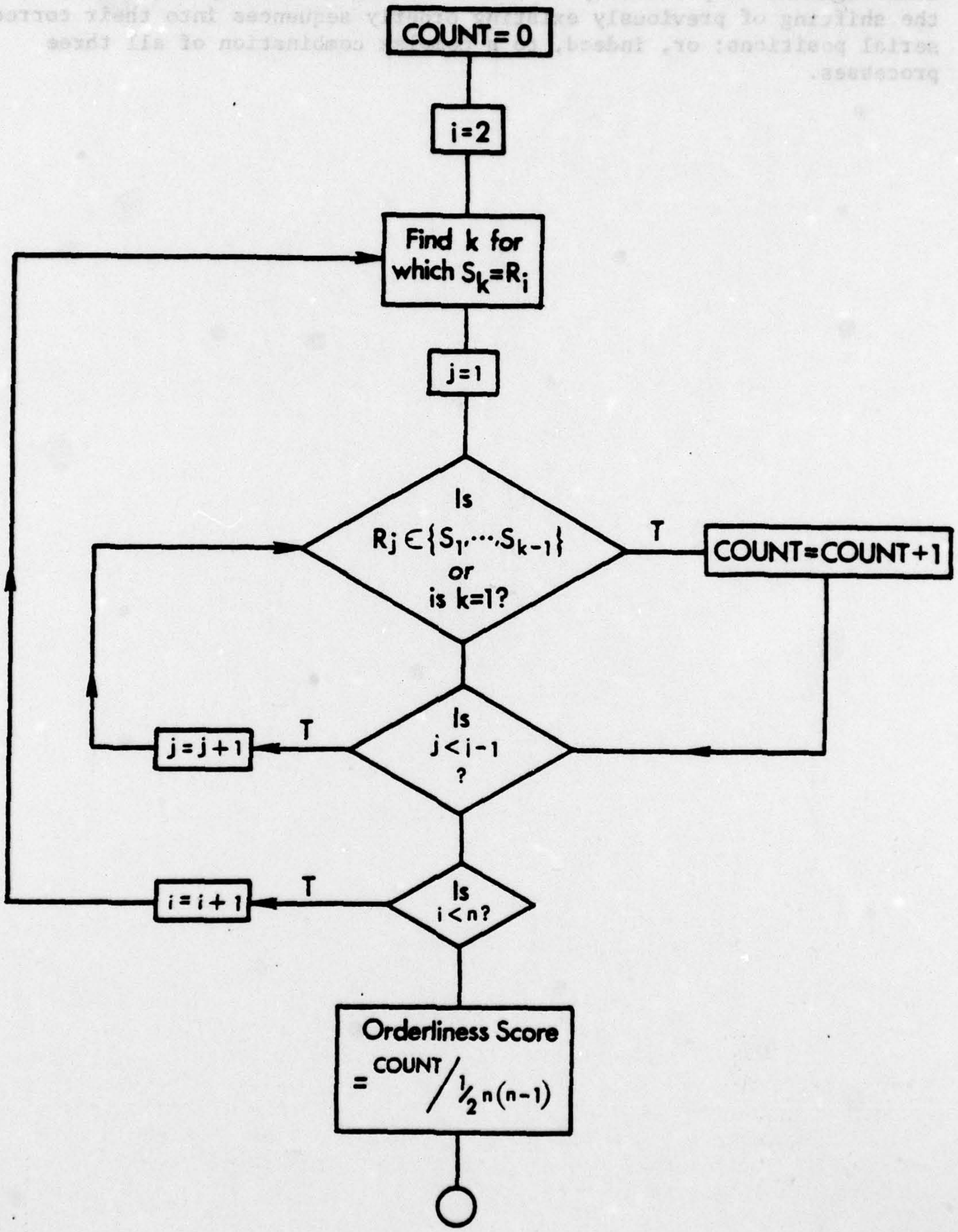

Figure 1. An Algorithm for the Computation of Orderliness Scores.

a tool to probe the fine structure of a subject's recall in order to study the details of the learning process. Recalled lists can now be analyzed to determine whether the changes from trial to trial are properly attributed to a difference in the number of items recalled, to the rearrangement of previously recalled items into orderly sequences, or to the shifting of previously existing orderly sequences into their correct serial positions; or, indeed, to a complex combination of all three processes.

Table 1

Orderliness Scores for the Permutations of a Four-Item List

Stimulus List: A B C D		
Recalled List	Elements of Order	Orderliness Score
A B C D	6	1.00
A B D C	5	0.83
A C B D	5	0.83
B A C D	5	0.83
A C D B	4	0.67
A D B C	4	0.67
B A D C	4	0.67
B C A D	4	0.67
C A B D	4	0.67
A D C B	3	0.50
B C D A	3	0.50
B D A C	3	0.50
C A D B	3	0.50
C B A D	3	0.50
D A B C	3	0.50
B D C A	2	0.33
C B D A	2	0.33
C D A B	2	0.33
D B A C	2	0.33
D B A C	2	0.33
C D B A	1	0.17
D B C A	1	0.17
D C A B	1	0.17
D C B A	0	0.0

APPENDIX D

1. Example of a 30-Word List

2. Example of a 30-Sentence List

A 30-Word List

1. rocket
2. ladder
3. rake
4. tooth brush
5. screw
6. popcorn
7. tiger
8. bowling ball
9. sandwich
10. coffee pot
11. bolt
12. mouse
13. comb
14. gas pump
15. shower
16. cookie
17. cowboy
18. lock
19. envelope
20. nut
21. roller skate
22. rage
23. rubber band
24. umbrella
25. cake
26. blanket
27. typewriter
28. trash can
29. ruler
30. apple

A 30-Sentence List

1. Sweat poured down the fireman's face as he moved closer to the flaming warehouse.

2. The tall lanky center stuffed the banketball through the hoop.

3. Thousands of bats flew out of the attic of the old house.

4. The frustrated writer threw his typewriter into the wastepaper can.

5. Three Christian men and a woman were thrown to the hungry lions in the Roman arena.

6. The big green sea turtle crawled over the hot sand of the beach toward the cool water.

7. The rattlesnake coiled its body and struck the pig on its snout.

8. The catfish swallowed the worm-covered hook and swam to the bottom of the lake.

9. The ocean liner hit a large iceberg that ripped a huge hole in its side.

10. The pack of wolves chased the tired moose through the snow.

11. A gust of wind tipped the sailboat over on its side.

12. The brown grizzly bear knocked a fish out of the stream onto the bank with its paw.

13. The golf ball shattered the windshield of the red convertible.

14. The oriental karate black-belt split a two-by-four in half with a blow of his bare hand.

15. The American soldier dropped a hand grenade down the hatch of the German tank.

16. The raccoon climbed onto the picnic table and knocked the picnic basket down to the ground.

17. The bull hooked the bullfighter with a horn and threw him back over his head.

18. The fat policeman ran down the middle of the street chased by a swarm of bees.

19. A red fox jumped out of an open window on the hen house carrying a white chicken in its mouth.

20. The parachute jumper landed in the middle of the lake.

21. The pretty young clerk fainted during the bank holdup.

22. The organ-grinder's monkey danced and clapped his paws as the organ-grinder turned the crank.

23. The bride cut the wedding cake and gave the groom the first piece.

24. The cyclone turned the new mobile home upside down.

25. The trash bag broke spilling garbage all over the kitchen floor.

26. The bowling ball bounced on the alley and rolled down the gutter.

27. A big black crow landed on the outstretched arm of the scarecrow.

28. The tightrope walker crossed over Niagara Falls.

29. The lion tamer cracked his whip at the unruly lion.

30. The little girl drew all over the wall with a purple crayon.